THE UNIVERSITY OF ALBERTA

CROP ECOLOGICAL AND HERBICIDAL STUDIES IN RELATION TO IMPROVEMENT OF SALINE LAKE-SHORE VEGETATION

BY

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA

SEPTEMBER, 1968

ABSTRACT

Experiments with a number of cultivated perennial grasses, legumes and cereal crops were conducted on saline soils of Miquelon Lake-shore, both in the greenhouse and under field conditions at the lake. Although some of the perennial grasses such as tall wheatgrass (*Agropyron elongatum* (Host) P.B.), slender wheatgrass (*Agropyron trachycaulum* (Link) Malte) and pubescent wheatgrass (*Agropyron trichophorum* Link) were fairly successful in greenhouse trials, none of the grasses or legumes was able to establish itself on the lake-shore under field conditions. Among the four cereal crops viz. barley, oats, wheat and winter rye, oats were the best in both greenhouse and field tests, followed by barley. Noticeable differences between the varieties of oats and barley were found in greenhouse trials. Of the varieties tested Husky barley and Glen oats were the most tolerant to saline conditions. However, no remarkable difference occurred between varieties of wheat and winter rye. Commercial fertilizers at 112 kg N/ha caused up to 2-3 fold increases in crop yields. Ammonium phosphate (16-20-0) resulted in higher yield increases compared to the "complete" fertilizers such as 13-13-13 or 21-21-21 at comparable rates of nitrogen. Even the best crop performance, however, was rather poor under the adverse field conditions.

In related studies involving control of Canada thistle by mowing, discing and crop competition on fertile black loam soil near Edmonton, winter rye was an excellent competitor against Canada thistle. Mowing followed by discing before seeding was superior to two repeated mowings prior to seeding rye. The mowing of thistles in the first week of August followed by discing late in the month just prior to seeding resulted in maximum control of Canada thistle without any significant reduction in yield of winter rye.

In another field experiment to determine effects of different seeding and clipping dates on winter survival and subsequent grain yield of Sangaste

winter rye and Kharkov 22 MC winter wheat, these crops seeded on June 14 and unclipped suffered extensive winter-killing. However, one clipping of such material in late July, August or mid September resulted in nearly complete survival. Early clippings resulted in slightly higher grain yields than later clipping of the earliest seeded material. After the later seeding dates (July 25 and August 28) no significant difference was found between grain yields of clipped and unclipped plots. Winter rye produced more forage at each clipping than did winter wheat. Grain yields were highest for both crops after August 28 seeding which also matured about 5 days later than earlier seedings. Final plant height was not appreciably affected by seeding date or clipping treatments.

Winter rye treated with different doses of picloram or of 2, 4-D ester applied once at five growth stages of the crop did not suffer any significant damage at any growth stage from the lowest doses of both herbicides (0.140 and 0.560 kg/ha respectively). Higher rates, however, caused severe injury and significant yield reductions. There was no appreciable difference between treatments at various growth stages. However the 4-5 leaf stage (late fall) apparently was most sensitive as indicated by various morphological abnormalities. Bushel weight, moisture and calcium percentage of grain were not affected to any appreciable extent by herbicide treatments. Protein and phosphorus percentage of grain tended to increase in association with reductions in yield.

ACKNOWLEDGEMENTS

I wish to express my deep appreciation to Dr. Wm. G. Corns under whose inspiring guidance the present investigation was carried out. His keen interest, constant encouragement and helpful criticism throughout the course of my research and during the preparation of this manuscript are gratefully acknowledged.

Special thanks are due to Mr. R. J. Schraa for the preparation of photographs and Mrs. D. Hayley for her assistance in preparing the final draft of the graphs. Thanks are also expressed to the Provincial Soil and Feed Testing Laboratory for carrying out the soil and grain analyses.

I am indebted to the National Research Council of Canada for extending the financial assistance to me and to the Department of Plant Science for the use of equipment and facilities.

Acknowledgement is made to the Dow Chemical Company for supplying picloram samples and to Dr. Thomas Lawrence of Experimental Farm, Swift Current, Saskatchewan for providing the seed of Orbit tall wheatgrass used in this study.

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INTRODUCTION

The research reported in this dissertation deals with part of a project initiated to study methods for control of perennial weeds in an area bordering Miquelon Lake, a migratory bird sanctuary about 40 miles southeast of Edmonton, Alberta, in the county of Camrose (Township 49, Range 21, west of 4^{th} Meridian). The low-lying saline areas along the lake-shore, where foxtail barley (*Hordeum jubatum* L.) forms the major natural cover, have for many years been infested with noxious perennials, Canada thistle (*Cirsium arvense* (L.) Scop.) and sow thistle (*Sonchus arvensis* L.). The wind disseminated seeds of these species aggravate the weed control problems on adjacent cultivated farm lands.

The decision of Camrose municipal officials in 1965 to spray by aircraft, on an experimental basis, the selective herbicide, 2, 4-D for control of thistles along part of the lake-shore was questioned by local wild-life scientists. As a result discussions were held amongst the interested governmental, municipal, and University of Alberta officials. It was agreed that experimental plot studies should precede any large scale weed control efforts and the Department of Plant Science, University of Alberta was assigned responsibility for research on vegetation control. Through courtesy of Mr. F. R. Wall an experimental site on the northwest end of the lake (N.E. 26, 49, 21, 4) was made available to the University for this work.

The objective of the study was to determine the feasibility of safe use of herbicidal or other methods to prevent seed spread or to overcome the perennial weeds while maintaining a suitable habitat or establishing an improved cover for the water-fowl and associated wild life. The approach was made by dividing the study into two related parts consisting

of:

(a) Control of Canada thistle and perennial sow thistle involving comparisons of herbicidal sprays in attempts to prevent seed production of the thistles or to eradicate them, as described elsewhere (28).

(b) Emphasis on potential crops for introduction and certain management practices. These included attempts to establish suitable competitive cereals, perennial grasses and legumes as discussed later. A definite gradation of salinity, decreasing gradually with the distance from the lake-shore provided an opportunity to divide the area into different zones and thus study the effect of varying pH and associated conditions on salt-tolerance of crops. Related to this work there was also opportunity for supplementary field and greenhouse studies including effects of added commercial fertilizers on barley and oats, competitive ability of winter rye and winter wheat after seeding and clipping at different times and tolerance of winter rye to certain herbicides.

Winter rye is known to be a strong competitor with weeds partly because of its early growth and vigorous root development in the spring. It also shatters its grain readily to reproduce itself. Because of these adaptations it was of interest to observe competitive ability, growth and survival of winter rye also under uncomplicated habitat conditions near Edmonton, as compared with winter wheat after seeding and clipping these crops at different times of the year. The results might relate to planning of an optimum mowing schedule for weakening thistle competition. Associated studies on response of winter rye to 2, 4-D and picloram were undertaken in anticipation of the possibility that if the rye were successful at Miquelon Lake, results could be improved if the area seeded to this crop could be sprayed at times when there would be maximum herbicidal injury to the thistles. It seemed likely that this and other studies on Canada thistle

competition and crop seeding and harvest times, done on fertile, black loam soil near Edmonton could have useful agricultural implications well beyond the primary objective of the project.

LITERATURE REVIEW

1. Saline Soils and Salt-tolerance of Crops

Salinity problems are of increasingly wide-spread occurence. The excessive accumulation of soluble salts in the soil is a potential, if not actual limiting factor for the productivity of irrigation agriculture everywhere (30). In Alberta data from soil surveys show that approximately 10 percent of the irrigated areas have been severely affected by salts. Saline soils occur sporadically throughout much of the Prairie and Parkland regions of the province. A recent study (26) under dryland conditions in the southwestern part of Alberta indicates that the extent of salinity is steadily increasing. The soluble salts present in the saline soils are variable both in kind and amount and also in their distribution throughout the soil profile.

Cereal Crops

It is important to consider the salt-tolerance of different crops and varieties that will give the best possible yields under saline conditions. In choosing a crop, factors in addition to salt-tolerance must be considered. Adaptation to climatic conditions, for example, is always a critical factor.

In 1941, Marshall (49) determined salt-tolerance limits for the growth of wheat, oats, and barley on Saskatchewan soils. The results indicated that of the three crops, barley is most likely to succeed on saline soils. The superiority of barley over other cereal crops has been shown by several workers under different conditions (5, 6, 7, 30, 70). The results for wheat and oats are less clearcut, however, oats generally have been reported more tolerant than wheat. Under certain conditions, for example, involving poor drainage (38), the black soil zone (6), and irrigated heavy textured soils (53) oats showed more salt-tolerance than barley. Mackie

(47) reports that if the climatic conditions are favorable, oats may produce a crop, where wheat and barley would fail.

Rye is also believed to be able to withstand considerable degrees of salinity (38). Although the literature about its salt-tolerance is controversial, the tolerance of rye seems to be somewhere between that of oats and wheat (70) or sometimes even better (38). As a hay crop rye has shown more tolerance than either wheat or oats (38, 70). So many different salts and combinations of salts occur in saline soils, that any classification of this type may be of general nature only. Moreover, all the three cereals viz. wheat, oats, and rye may be classified in the same group, the so called "medium", or "semi" - salt-tolerant crops (7, 38, 70).

Forage Crops

Many cultivated forage crops, including perennial grasses, show considerable salt-tolerance. Among the commonly grown perennial grasses in Western Canada, Tall wheatgrass, *Agropyron elongatum* (Host.) P.B. (21, 41); Slender wheatgrass, *Agropyron trachycaulum* (Link) Malte, (21, 64); and Russian wild rye-grass, *Elymus junceus* Fisch, (64) have been reported to be most salt-tolerant. Tall wheatgrass is specially adopted to wet saline soils in all parts of Canada (41). Legumes like alsike clover and alfalfa are highly resistant to salts, but it may be difficult to establish good stands of these crops, particularly on wet saline soils (21).

Varietal Differences

There have been many reports that different varieties of some crops vary in their tolerance to salinity. California Mariout variety of barley (4) and Orbit variety of tall wheatgrass (41) have shown definitely better

salt-tolerance at all stages of growth than other known varieties. Similar varietal differences with other crops such as wheat and cotton etc. have been reported (4, 5, 7, 70).

Salinity and Water Availability

In saline soils the principal factor depressing plant growth is the decrease in available water due to high osmotic pressure of the soil solution. There is much evidence to indicate that an increase in the osmotic pressure of the solution may result in a decrease in the water uptake by plant roots (65). In addition to the factor of osmotic pressure of the solution, the nature of the salts present may exert an important influence on plant growth. On a weight or equivalent basis, chloride salts for example, are more inhibitory to the growth of plants than sulphate salts (65, 70). The work on solonetzic soils of Alberta has also shown the poor water-transmission properties of these soils in both surface and sub-surface layers (9).

Improvement of Saline Soils

Several practices have been recommended and used to improve saline soils. These include leaching, drainage, irrigation (with salt-free water), tillage, use of salt-tolerant crops and fertilizers (70). The use of salt-tolerant crops accompanied by suitable agronomic practices to overcome the salt problem has been discussed by a number of authors (7, 9, 70).

With regard to effect of added fertilizers Luken (45) on the basis of his experiments under dryland conditions in Saskatchewan reported that wheat yields could be substantially increased on moderately saline soils by application of high rates of nitrogen and phosphorus fertilizers. No yield improvements due to fertilizer application were, however, noted from

a soil with a 24 - mmhos/cm salinity concentration. Application of 112 kg nitrogen/ha (100 lb/A) increased the wheat yields nearly 15 bu/A on solonetzic soils at Vegreville, Alberta (9). Ferguson _et. al._ (19) found much higher plant response to phosphorus (calculated as percent of controls) on moderately saline than a non-saline soil. Phosphorus absorption by wheat plants increased with increasing salt-concentration, reached a maximum when the saturation soil extract measured approximately 6 - mmhos/cm, and then declined with further increases in salt-concentration. Significant increases in the fodder yield of a clover (_Trifolium alexandrium_) were reported with an application of 100 lb P_2O_5/A (14). According to Wilson (76) forage crops grown under saline conditions should be well fertilized with nitrogen to compete with salt-tolerant weeds such as foxtail barley (_Hordeum jubatum_). Thus it seems clear that there may be beneficial effects of fertilization provided the drainage is good and salinity is not extremely severe.

2. Cropping and Mowing for Control of Canada thistle

Canada thistle (_Cirsium arvense_ (L.) Scop.) is one of the most troublesome weed species in Canada and the United States. The plant is perennial and dioecious, and reproduces vegetatively as well as from seed. Since a small piece of the root can give rise to a new plant, reproduction and spread occur in a short time. Before the use of modern herbicides, mowing and cropping were the only methods available for the control of Canada thistle.

There is no available literature with specific reference to effects of mowing and crop competition on control of Canada thistle under soil conditions similar to those noted above. Some of the general information however, serves as broad background knowledge in relation to competition between thistles and crop under more nearly normal soil conditions.

Cropping and Competition

Certain cropping systems were found to be economical means of controlling Canada thistle in Idaho (52). An effective control of Canada thistle was obtained by Thrasher *et. al.* (68) in studies involving competition with certain forage species such as Alta Tall Fescue. Mather (50) reported that Canada thistle in Western Canada was readily and economically eradicated by seeding infested land to forage crops. He also indicated that alfalfa was an effective competitor of Canada thistle because of the vigorous growth habit and rapid recovery of alfalfa after mowing. Similar results have been reported by other workers (18, 32, 66).

Pavlychenko and Harrington (60) found that amongst cereal crops barley varieties were the most successful competitors against weeds, followed in order by Prolific spring rye, Marquis wheat, Banner oats, and Crown flax. Winter rye, partly because of its early growth in the spring, has substantial competitive power. Thurston (69) reported very effective control of wild oats by dense stands of winter wheat and winter rye. Hodgson (33) recommended perennial forage crops and autumn-sown cereals as competitors for Canada thistle.

Mowing of Canada thistle

Welton *et. al.* (75) studying organic food reserves in relation to eradication of Canada thistle, showed that systematic mowings one month apart through four seasons removed practically all the Canada thistle. Mowing or clipping once a year in the early bud stage prevented seed development, but did not eradicate the plants (43). However, in combination with a good smother crop such cutting helped reduce the stand and might have eventually destroyed all thistle plants. In another study mowing after each grazing period for 4 years almost eliminated Canada thistle (66). Heads of Canada thistle, open for 11 days or longer, produce

a high percentage of viable seeds (15). Mowing of stands to prevent seeding must, therefore, be done not later than one week after flowering.

3. Effect of Clipping and Seeding Dates on Winter Survival of Autumn-Sown Cereals

As mentioned in the section above, mowing Canada thistle in the fall, in combination with a competitive crop can destroy almost all thistle plants. Naturally then, the effects of mowing on associated competitive crops need to be known. The autumn-sown cereals used for such studies in the present investigation were winter wheat and winter rye.

The seeding dates recommended to Alberta farmers for winter rye and winter wheat vary from the first two weeks of August in Northern Alberta, to the first two weeks of September in Southern Alberta. In Central Alberta, the best seeding date for winter wheat at Edmonton was found to be approximately August 28 (13). Work at Nappan, Nova Scotia (48) has indicated that early seeded winter rye can be used for green feed in the seeding year and still produce a good grain crop the next year. Seeding the crop on June 1st and clipping every four weeks gave normal grain production in addition to about a ton of forage. The frequency of cutting forage in the fall did not affect grain yields. Utilization of winter small grains for both grazing and grain production has been customary in Georgia (55). Winter rye is used for this purpose more than other winter-seeded cereal crops. There are several reports (34, 55, 67, 72) showing that winter rye produces more forage than either wheat or oats. Clipping any winter cereals for spring forage reduced grain yields, though the effect was less in favorable growing seasons (34). However, grazing during fall (67) or one clipping early in spring (1, 55, 73) gave no reduction in the grain yield of winter wheat and winter rye. Whether or not yields are affected by the grazing or cutting practice, therefore, seems to vary depending upon various incompletely predictable conditions.

4. Effect of 2, 4-D and Picloram Applied at Various Growth Stages of Winter Rye

2, 4-D

2, 4-D (2, 4-dichlorophenoxyacetic acid) has been used for many years to control deep-rooted perennial weeds, with varying degrees of success. Satisfactory control of Canada thistle and perennial sow thistle has been obtained by spraying 2, 4-D alone (18, 63), or using it in combination with suitable competitive crops (16, 32, 52). At present 2, 4-D is the most widely used selective herbicide for the control of weeds in cereal crops. It has been recognized for sometime that cereals, while relatively resistant to 2, 4-D, do suffer damage at some growth stages. There are numerous reports on the effect of herbicides, especially 2, 4-D and MCPA, when applied at various growth stages of spring wheat and barley in Western Canada, but little published work is available on winter wheat and almost none on winter rye in this connection.

The research concerning the division of the growth period of cereal crops into susceptible and resistant stages has led to rather variable conclusions. In wheat, for example, various workers have described the susceptible stages as early seedling stage (24, 39, 58), spikelet initiation (56, 62), advanced tillering stage (54), and from the boot stage through early heading (24, 39, 58, 62). The resistant stages similarly, have been recognized as pre-emergence (24, 58), emerging stage (58), early tillering stage (54), early jointing stage (61), the period after seedling stage but before the boot stage (25, 58), and at times close to maturity (61). These inconsistencies may be partly due to interaction effects with environmental conditions, which were different on the different dates of 2, 4-D application. Conspicuous external morphological changes were induced at certain susceptible stages reported above, among which onion-like leaves and spike and

spikelet abnormalities were common. An increased protein percentage of grain has also been reported following 2, 4-D application. However, protein percentage was inversely associated with yield, and when no yield changes occurred with treatment, 2, 4-D had no appreciable effect on protein content (39, 61).

Despite the fact of certain inconsistencies in results from place to place and time to time it has been possible to develop generally reliable recommendations with regard to safe stages of growth of cereal crops for treatment with 2, 4-D viz - from the full 3-leaf stage to the flag leaf (shot-blade) stage of growth for spring wheat and barley and at early stage in spring for winter wheat and winter rye (44). Treatment during the fall, or in late spring after the crop has reached the shot-blade stage of growth is not recommended for winter wheat and winter rye (39, 44).

Picloram

In 1963, picloram (4-amino-3, 5, 6-trichloropicolinic acid) was introduced as an experimental herbicide (29) by Dow Chemical Company. Picloram is a highly active, systemic compound, effective on a wide range of woody plant species and noxious perennial weeds (31, 74). Results with Canada thistle, in particular, have been very encouraging (2, 29, 31, 40). It is also a quite effective and selective herbicide at lower rates of application for control of certain annual weeds in cereal crops (29). Available evidence indicates that the herbicide will not create any hazard to livestock or wildlife, including aquatic organisms, when used according to recommendations (46, 74). Field testing indicates that picloram when used at dosages sufficient to control perennial thistles, may persist in the soil in sufficient amount to reduce production of most succeeding crops for at least one season

and possibly two (31). Although, at time of writing, formulations of picloram are not yet registered for use on cultivated cropland, research agencies are continuing studies on the use of picloram alone or in combination with other chemicals for selective weed control in cereal grains.

Significant reductions in the height of wheat have been reported by application of picloram at different growth stages (22, 25, 27, 36, 71). However, no significant reductions in the yield were found from doses varying from 0.25 - 1.44 oz/A. Small doses of picloram mixed with 2, 4-D, MCPA, and Mecoprop, applied at 3 - 5 leaf stages on wheat, oats, and barley have shown no reductions in yield (25, 42, 51). Percentage germination of barley was reduced by 0.280 kg/ha (4 oz/A) of picloram (35). No decrease in the bushel weight of wheat was noticed after treatment at 5 - 6 leaf stage with 0.070 kg/ha (1 oz/A) of picloram (27). At susceptible stages of wheat when picloram reduced seed yields, an increase in the protein percentage of the grain was found as a result of picloram treatment by Nalewaja (57). Thatcher wheat treated with picloram at 1, 2, 3, 4, 5, and 6 - leaf stages of wheat showed no significant difference between the stages with regard to susceptibility to the herbicide (71). Application of 0.070, 0.140 and 0.280 kg/ha of picloram between the tillering and full head stages of oats, barley, spring wheat and spring rye showed no difference between the stages of application (35). Nalewaja (57) reported that 2-4 leaf stage and the time after heading of Selkirk wheat were the stages most tolerant to picloram, and early tiller to boot stage were the most susceptible. In an attempt to control scentless mayweed (Matricaria maritima L. var. agrestis), Carder (12) applied 0.070. 0.140, 0.280 and 0.420 kg/ha to Dakold winter rye at one growth stage, when rye was about 10 cm. high in the spring. The observations taken at milk-stage showed injury to the crop by the later two doses of herbicide

(0.280 and 0.420 kg/ha). However, no harmful effects resulted from the lower doses. We have been unable to find any additional publication on the effects of picloram on winter rye.

The foregoing review provides general background information on the main topics of this study. Some additional literature having specific relevance to our results will appear later under the heading, Results and Discussion.

MATERIALS AND METHODS

1. Saline Soil and Salt-tolerance of Crops

A. Zonation

Work on the salt-tolerance of crops was done on the saline shore of Miquelon Lake. Several strips running from the lake-shore upwards to the poplar trees were selected. The total length of these strips varied because of the irregular lake-shore. Each strip was divided into 5 different zones depending on the vegetation present. Although foxtail barley (*Hordeum jubatum* L.) was a widely distributed major part of the natural cover along the lake-shore, Canada thistle (*Cirsium arvense* (L.) Scop.), sow thistle (*Sonchus arvensis* L.) and other species were abundant in parts of the area and zonational differences on the basis of apparently dominant species were readily recognizable. Figure 1 is a diagramatic representation of three strips, which were used for one of the experiments, showing different zones, total length of each zone in every strip, the dominant vegetation in each zone and soil pH. The zones are numbered from I to V starting from the lake-shore.

Table 1 shows the percentage cover of the major dominant species in each zone. These data were taken in August, 1966, before the experiments were started.

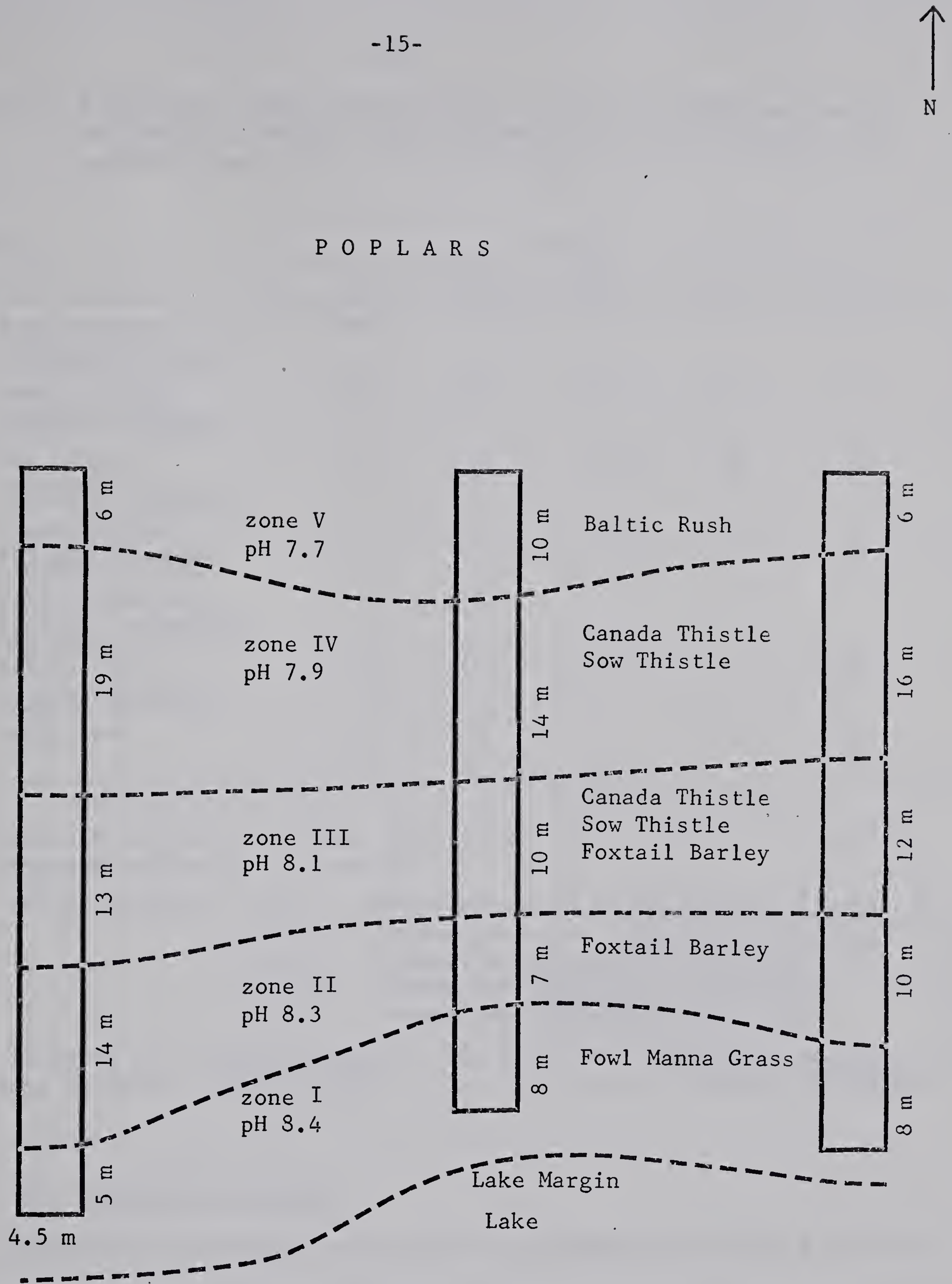


Fig. 1. Diagramatic representation of different zones, their major vegetation types and soil pH in the experimental areas at Miquelon Lake.

Table 1. Percentage cover (average for 3 strips) of different species of plants in various zones extending back from Miquelon Lake margin (Figure 1).

Species	Zones I	II	III	IV	V
1. Fowl mannagrass (Glyceria striata)	80	5	--	--	--
2. Foxtail barley (Hordeum jubatum)	10	80	20	10	--
3. Sow thistle (Sonchus arvensis)	--	5	50 *	60	10
4. Canada thistle (Cirsium arvense)	--	--	20 *	20	5
5. Prairie bulrush (Scirpus paludosus)	--	5	5	5	5
6. Baltic rush (Juncus balticus)	--	--	--	--	60
7. Others **	10	5	5	5	20

* - Both sow thistle and Canada thistle were much stunted in zone III as compared with those in zone IV.

** - Others include - Zone I - Saline goosefoot (Chenopodium salinum)- 10%
Zone II - Saline goosefoot (Chenopodium salinum) - 5%
Zone III - Dandelion (Taraxacum officinale) - 5%
Zone IV - Dandelion (Taraxacum officinale) - 5%
Zone V - Dandelion (Taraxacum officinale) - 3%

Many flowered Aster (Aster pansus) - 5%; Red clover (Trifolium pratense)- 4%; Kentucky bluegrass (Poa pratense) - 4%; and Quackgrass (Agropyron repens) - 4%.

B. Description of Soil

Composite soil samples were taken in the summer of 1966 and 1967 from each zone from three different strips, each strip being a replicate. Three depths used for sampling were, 0 - 10, 10 - 20, and 20 - 30 cm. The samples were air dried and passed through a 2 m.m. sieve. The pH of the saturated paste; electrical conductivity of the saturation extract, available amounts of major soil nutrients; percent carbon; and organic matter were determined

by the Agricultural Soil and Feed Testing Laboratory of the Alberta Department of Agriculture. The procedures followed for these determinations were the ones commonly used by the Soil and Feed Testing Laboratory. $CaCO_3$ was listed as low, medium and high from visual observations of effervescence. Extractions and determinations of exchangable Na, K, Ca, Mg; cation exchange capacity (C.E.C.), and mechanical analyses were performed by the Alberta Soil Survey Laboratory. With some minor modifications the methods used in these analyses were those outlined in U.S.D.A. Handbook 60 (70). The attributes of the soil in the experimental areas are presented in Tables 2 and 3.

Table 2 shows that both pH of the soil and electrical conductivity of the saturation extract (E.C.) decreased with increasing distance from the lake-shore. A slight decrease in both was also observed at the greater depths. Nitrogen and phosphorus were almost negligible in all the zones while potassium was present in very high amounts, particularly in the zones closest to lake-margin. Soluble anions (Cl^- and SO_4^{--}) were present in higher concentrations near the lake. Organic matter was low to medium throughout the area. Free-lime was slightly lower near the lake-margin.

Data in Table 3 indicate that Na, K, and Mg were quite high in the zones closest to lake-shore, but decreased with increasing distance from the lake. Ca, on the other hand, showed an opposite trend i.e. it was low in zones close to the lake and increased farther from the shore (with the exception of zone V). Zone V, the zone farthest from the lake had low amounts of Na, K and Cl and lower amounts of SO_4. Further it exhibited lower pH and electrical conductivity. The cation exchange capacity showed a trend very similar to pH and E.C. i.e. it decreased with distance from the lake.

Table 2. General chemical characteristics, pH, organic matter and soluble constituents (soil fertility analysis) of soil adjacent to Miquelon Lake.

Zone	Depth (cm.)	pH	E.C. mmhos/ cm.	Kg/ha of available** N	P	K*	O.M. %	Sol. anions meq./100 gms. Cl⁻	SO_4^{--}*	$CaCO_3$
I	0 - 10	8.5	12.2	1.5	3.4	672+	6.0	0.10	16.7+	M
	10 - 20	8.4	11.0	1.5	2.2	672+	5.9	0.09	16.7+	M
	20 - 30	8.4	9.5	1.5	2.2	672+	5.5	0.08	16.7+	M
	Means	8.4	10.9	1.5	2.6	672+	5.8	0.09	16.7+	M
II	0 - 10	8.3	11.8	1.9	4.0	672+	5.5	0.07	16.7+	H
	10 - 20	8.3	9.5	1.1	2.2	672+	5.3	0.05	16.7+	H
	20 - 30	8.2	8.0	1.1	1.9	672+	5.0	0.03	16.7+	M
	Means	8.3	9.8	1.4	2.7	672+	5.3	0.05	16.7+	H
III	0 - 10	8.1	10.0	1.5	3.4	672+	5.2	0.09	16.7+	H
	10 - 20	8.1	8.2	1.9	1.9	672+	4.1	0.06	16.7+	H
	20 - 30	8.0	7.0	1.1	1.1	672+	4.1	0.04	16.7+	H
	Means	8.1	8.4	1.5	2.1	672+	4.5	0.06	16.7+	H
IV	0 - 10	8.0	4.2	2.6	3.4	492	4.3	T	12.5	H
	10 - 20	7.9	5.0	2.2	3.1	529	3.1	T	14.6	H
	20 - 30	7.9	5.9	1.9	1.9	575	2.2	T	15.3	H
	Means	7.9	5.0	2.2	2.8	532	3.2	T	14.1	H
V	0 - 10	7.8	1.8	2.2	5.9	393	2.1	NIL	4.2	H
	10 - 20	7.7	2.9	1.5	1.9	411	1.9	NIL	13.9	H
	20 - 30	7.7	3.2	1.5	1.9	493	1.4	NIL	14.6	H
	Means	7.7	2.6	1.7	3.2	432	1.8	NIL	10.9	H

* For K- 672+ indicates a level of abundant supply and for sulphate- 16.7+ indicates a level sufficient to restrict crop growth, irrespective of cation with which it is bound. T - Trace, M - Medium, H - High.

** Kg/ha x 0.892 = lb/A.

Table 3. Exchangeable salts and mechanical analyses of soil adjacent to Miquelon Lake.

Zone	Depth (cm.)	Exchangeable Analysis* meq/100 gms.				C.E.C. meq/100 gm.	Mechanical Analysis		
		Na	K	Ca	Mg		Sand	Silt	Clay
I	0 - 10	13.9	2.0	21.4	21.1	23.4	4	57	39
	10 - 20	13.9	2.0	20.2	22.8	24.1	4	57	39
	20 - 30	11.7	1.6	20.8	18.6	25.1	3	76	21
	Means	13.2	1.9	20.8	20.8	24.2	3.7	63.3	33.0
II	0 - 10	7.0	1.7	26.1	15.6	14.8	31	24	45
	10 - 20	6.8	1.7	23.3	17.7	20.3	11	51	38
	20 - 30	5.7	1.7	26.1	19.5	21.7	8	53	39
	Means	6.5	1.7	25.2	17.6	18.9	16.7	42.7	40.6
III	0 - 10	5.7	2.0	31.0	15.8	18.5	21	51	28
	10 - 20	1.9	1.5	38.5	13.8	18.2	13	57	30
	20 - 30	1.1	1.1	40.6	13.7	19.4	16	50	34
	Means	2.9	1.5	36.7	14.3	18.7	16.7	52.7	30.6
IV	0 - 10	2.9	1.0	25.6	6.1	13.3	48	34	18
	10 - 20	5.2	0.9	44.7	6.1	15.2	28	53	19
	20 - 30	4.3	0.9	42.3	8.3	13.4	35	47	18
	Means	4.1	0.9	37.5	6.8	14.0	37.0	44.7	18.3
V	0 - 10	0.1	0.5	17.4	-	5.6	82	15	3
	10 - 20	0.1	0.4	30.5	-	9.7	61	29	10
	20 - 30	0.2	0.4	33.4	-	7.7	62	27	11
	Means	0.1	0.4	27.1	-	8.3	68.3	23.7	8.0

* High Free salt content in soil which is not on exchange sites makes the sum of the cations much too high.

Based on the results of soil analyses it seems to be a safe conculsion that this particular soil was a saline soil (according to the definition given in Glossary of soil terms in Canada (11)) except that of Zone V which has an E.C. of less than 4 mmhos/cm. The pH of soil, on an average, does not exceed the limit of 8.5 in any case. Although sodium adsorption ratio (SAR) and exchangable sodium percentage (ESP) were not determined, it is very unlikely that the ESP will exceed the limit of 15%. Zone I which was closest to lake-shore might fit the classification of saline-alkali soil but, in general, it seemed advisable to use the term "saline soil" for the purpose of this thesis.

The mechanical analyses reported in Table 3 indicate that percentage of clay was higher in the first three zones (closer to lake) but decreased gradually to become very low in zone V. The sand portion of the soil showed a trend opposite to clay i.e. it increased from a very low to very high percentage with increasing distance from the lake. Silt accounts for about 50% of the soil fractions in most of the cases (except Zone V). It can also be generalized that percentage of sand was higher in the top 4" of soil as compared with sub soil in every zone.

It was found that differences in soil analyses were associated with the vegetational differences of the indicated zones. Had the zones been delineated according to soil analyses, they would have been approximately the same as they were on the basis of their vegetative cover.

Measurements of the water-table were obtained in every zone through observation wells 10 cm. in diameter. Two wells one at each boundary were used for each zone. Measurements were made in spring (May 10) at the time of seeding of crops and in fall (September 12) after harvesting of crops in two consecutive years. The data are presented in Table 4.

Table 4. Depth to water table, in cm. in different zones at Miquelon Lake (average for two years).

Zone	Spring	Fall
I	42	95
II	64	117
III	88	141
IV	104	157
V	116	169

C. Greenhouse Experiments

i) General Preparation of Materials

Uniform soil samples approximately 30 cm. in depth were brought from each zone, air-dried, ground to pass a 5 m.m. sieve, and used for greenhouse studies during the winter. Experiments in the greenhouse were conducted with controlled minimum temperature of 18.5°C. During the winter the temperature was approximately constant at this level. However, during the summer the temperature was often in excess of 35°C. Supplementary lighting was given during the winter to keep the day-length approximately at 16 hours by using 200 watt incandescent bulbs. The bulbs were placed 60 cm. apart and approximately 90 cm. above the pots, giving a light intensity of approximately 500 ft. - C at foliage level. In the growth-chamber the temperature was maintained constant at 21°C throughout the growth period of crops. A day-length of 14 hours was provided with a light intensity of approximately 1500 ft. - C at foliage level.

All the plants were grown in well drained 15 cm.-diameter plastic pots which were filled with approximately 1800 gm. of soil. The soil used for control treatments in all the experiments was a standard mixture of three

parts of Edmonton black loam soil to one part of sand and one part of peat. Tap water was applied to the soil surface once a day to keep the pots in moist condition. During the growth period, the plants were fumigated to prevent insect and disease damage.

Randomized plot designs with three replicates were used for all experiments except the one with perennial grasses and legumes in which only two replications were used.

Plants were harvested, in most cases, at early heading stage by severing them at the soil surface. The harvested material was oven dried at 110°C and weighed. Where data were analysed statistically, significance at the 5% level was determined by analysis of variance and least-significant difference (LSD) test as developed by Fisher and Yates (20).

ii) Experiments with Perennial Grasses and Legumes on Soil from Miquelon Lake-shore

The grasses included in this study were Tall wheatgrass (*Agropyron elongatum* (Host) P.B.); Slender wheatgrass (*Agropyron trachycaulum* (Link) Malte); Intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv); Pubescent wheatgrass (*Agropyron trichophorum* Link); Bromegrass (*Bromus inermis* Leyss); Reed canary-grass (*Phalaris arundinacea* L.); Orchardgrass (*Dactylis glomerata* L.); and Timothy (*Phleum pratense* L.). The two legumes used were Alfalfa (*Medicago sativa* L.) and alsike clover (*Trifolium hybridum* L.).

Soil from each of the five zones and standard 3:1:1 mixture (control) were included in this experiment. 50 seeds of each species were seeded in 15 cm. diameter, plastic pots and covered with a thin layer of soil. Treatments were replicated twice. Observations on germination, survival, and height of plants on 5 randomly selected plants in each pot were made at weekly intervals until harvest time. Plants were harvested after 55 days

and dry weight was recorded.

iii) Experiments with Cereal Crops on Soil from Miquelon Lake-shore

The four common cereal crops included in this experiment were wheat var. Thatcher; barley var. Parkland; oats var. Victory and winter rye var. Sangaste. Soils from each of the 5 zones and standard 3:1:1 mixture (control) were used in 15 cm diameter plastic pots. Ten seeds of uniform size were planted at 2 cm depth and covered with a thin layer of soil. Records on germination; number of plants per pot; plant height and number of leaves per plant on 5 randomly selected plants in each pot were made weekly. Plants were harvested after 42 days and oven-dry weight was recorded.

iv) Experiments with Different Varieties of Cereal Crops on Soil from Miquelon Lake-shore

Four commonly grown varieties of each of the four cereal crops included in this study were:

Wheat - Marquis, Canthatch, Saunders, Chinook.

Rye - Winter varieties - Dakold, Antelope, Sangaste and Spring var. Prolific.

Barley - Husky, Betzes, Gateway 63 and O.A.C. 21.

Oats - Glen, Garry, Abegweit, Eagle.

Three varietal trials (two in a greenhouse and one in a growth chamber) were conducted on soils of zones I, II and IV and included some or all of the above mentioned varieties. Observations on germination, height of plants and number of leaves per plant on five randomly selected plants in each pot were taken once a week. Plants were harvested after 45 days in the first and second trial, and after 148 days in the third trial. Vegetative matter produced from each pot was recorded after drying in an oven at 110°C. Grain yield was also recorded in the third trial.

v) Experiments with Fertilizers on Soil from Miquelon Lake-shore

The varieties of cereal crops used in these trials were wheat var. Thatcher; barley var. Husky; winter rye var. Sangaste; and oats var. Glen. Ten seeds were planted in 15 cm diameter, plastic pots at 2 cm depth and covered with thin layer of soil. The fertilizers used were 16-20-0 (also known as ammonium phosphate); 13-13-13; and 21-21-21 (a liquid fertilizer).

There were three fertilizer trials, two in a greenhouse and one in a growth chamber. Soils of zones II and IV, the four cereal crops, and one or all of the three fertilizers were included in these tests. Observations on germination; height of plants; and number of leaves per plant on 5 randomly selected plants in each pot were taken weekly. Plants were harvested after 42 days in the first and second trials and after 135 days in the third trial. Vegetative dry matter produced in each pot was weighed and in the third trial grain weight was also recorded.

D. Field Experiments

Experiments in the field at Miquelon Lake were conducted with different perennial grasses, legumes and annual cereal crops to test the salt-tolerance of these species. The area was first mowed with a sickle-mower and then cultivated twice with a power-operated garden rototiller. The seeds were broadcast by hand and raked lightly into the soil. Randomized-plot designs with three replications were used for all experiments.

Observations on number of plants per square foot, number of leaves per plant and height of plants on 5 randomly selected plants in each pot were recorded at 15-day intervals. Notes were also made on the general appearance of crop plants such as color of leaves, burning or drying of leaf tips and vigor. Yields were determined by harvesting duplicate random square-meter samples from each plot. Both grain and straw yields were recorded.

i) Growth of Perennial Grasses and Legumes at Miquelon Lake.

Experiments were conducted in the summer of 1966 and 1967. All the grasses and legumes mentioned in section (ii) of part 'C' were included in 1966, but only tall wheatgrass, slender wheatgrass, pubescent wheatgrass, bromegrass, and alsike clover were tested in 1967. A variety of tall wheatgrass called Orbit, which has been recently developed in Canada (41) and is said to be best for saline soils was also included in the 1967 test. Seed rates one or two pounds per acre higher than commonly recommended to farmers in Alberta were used. The plots were located only on zones I and II in each replicate i.e. under the most difficult conditions for growth.

ii) Growth of Winter Rye at Miquelon Lake

Three 4.5 meter wide strips running from the lake-shore back to the poplar trees were selected, each strip representing a replicate. Each replicate was mowed and within it a strip 1.8 meter wide was cultivated and seeded; 0.9 meter was seeded without cultivation; 0.9 meter was cultivated but left unseeded; and the remaining 0.9 meter was left as control without giving any cultivation or seeding. General layout of these strips is shown in Figure 1. Seeds of winter rye var. Sangaste were broadcast by hand at the rate of 100 kg/ha on August 24, 1966 and raked into the soil.

iii) Growth of Barley and Oats at Miquelon Lake

A uniform 49 x 20 meter area was selected, mowed and cultivated twice with a garden rototiller. The whole area was then divided into six 3 meter wide strips running back from the lake-shore to the poplar trees. Three of these strips were seeded with Husky barley and the remaining three with Glen oats, using a randomized split-plot design. Seeds were broadcast at the rate of 100 kg/ha for barley and 112 kg/ha for oats on May 23, 1967 and raked into the soil.

iv) Response of Cereal Crops to Fertilizers at Miquelon Lake

A fairly uniform area of 25 x 18 meters was prepared and divided into 3.6 x 18 meter plots for different treatments. A split-plot design with two randomized block replications was used. The main plot treatments were the two crops, Husky barley and Glen oats; the sub-plot treatments were applications of 0 and 112 kg N/ha in the form of ammonium sulphate (21-0-0) and ammonium phosphate (16-20-0). Fertilizers were broadcast by hand before seeding of the crop and mixed with the soil. Seeds were broadcast on May 24, 1967 at the rates of 100 and 112 kg/ha for barley and oats respectively and raked into the soil.

2. Cropping, Mowing and Discing for Control of Canada thistle (*Cirsium arvense*)

An experiment designed to study the competitive ability of winter rye when growing in competition with Canada thistle on productive black loam soil was conducted during 1966-1967 at the University farm at Ellerslie near Edmonton. The Canada thistle infestation used in this experiment grew from root - pieces established by Mr. Fa-Yan Chang, a graduate student, in 1964 originating from a single plant. The average density on August 8, 1966 was 42 shoots/m^2. At this time thistles were mowed with a tractor-driven rotary mower. The field was then divided into triplicate 4.5 x 4.5 meter plots in a randomized-block design for different treatments. One treatment involved a second mowing with a sickle mower and another treatment was discing, each followed by seeding of Sangaste winter rye (67 kg/ha) on August 26, 1966. Some plots in both treatments were left unseeded. A 4.5 meter wide strip of winter rye was also seeded on clean land adjacent to thistle plots. This was kept weed-free during the course of experiment to serve as a 'control'.

Data were collected concerning the crop and weed at 15-day intervals until harvest time. Records included number of rye plants/m row; number of

thistle plants/m^2 in 5 randomly selected places in each plot; height of plants; number of leaves per plant and number of tillers per plant, for rye only, recorded on 5 randomly selected plants in each plot. Grain yield for rye and dry matter production for thistles were determined by harvesting duplicate random square-meter samples from each plot preparatory for analysis of variance (20).

3. Effect of Clipping and Seeding Dates on Winter Survival of Autumn-Sown Cereals

Earlier work in the Division of Weed Science at the University of Alberta involved herbicidal experiments with winter rye seeded without vernalization in spring. In undisturbed control material there was abundant forage but no grain production by fall, and none of this material survived the winter. However, areas of this early seeded material (May 24, 1966) which were clipped in fall (September 6, 1966) for yield determinations survived the winter and matured normally the next summer. This unexpected and interesting response led to more intensive experiments reported here.

The present study was conducted during 1967-68 on black loam soil at the University farm at Ellerslie. Sangaste winter rye and Kharkov 22 MC winter wheat were seeded at different dates and were managed to produce one or more crops of forage in the same year and a subsequent grain crop next year. Seeding was done at the rate of 67 kg/ha and at a depth of about 5 cm. below the soil surface by a tractor-driven seed drill. All the plots were hand-weeded during the course of experiment.

A triplicate, randomized split-plot design was used, with the two crops (winter wheat and winter rye) forming the main plots, dates of seeding the sub plots and clipping treatments the sub-sub-plots. The three dates of seeding were June 14, July 25 and August 28, 1967, for both crops. The three clipping treatments were (a) clipping on July 25, (b) clipping on

August 28, and (c) clipping on September 15, 1967. In the first seeding date all of the three clipping treatments were applied; in the second seeding date only two (b and c); and in the third seeding date only one clipping treatment (c) was applied. The remainder of the plots in the second and third seeding date were left as controls.

For the clipping treatments, plots 0.9 x 6 meter were laid out along the seeded rows. A 0.9 meter wide control plot was left between every two clipping treatments and 1.4 meter on both edges of sub-sub-plots. Clipping was done by cutting a 0.9 meter swath with an ordinary lawn mower with a cotton bag attached on one side to collect the forage, and both fresh and dry weights were determined. Dry matter was determined by oven-drying two 500-gm. samples for each plot at each cutting.

Observations on number of plants/m; height of plants; number of leaves and number of tillers per plant were taken on 5 randomly selected plants in each plot early in spring (May 23, 1968) and at harvesting time (August 12, 1968). Any differences in the times to maturity were also recorded. Grain yield for analysis of variance (20) was determined from duplicate random square-meter samples from each plot.

4. <u>Response of Winter Rye to 2, 4-D and Picloram Applied at Different Growth Stages</u>

This experiment was conducted on black loam soil at the University farm at Ellerslie. A split-plot design with three randomized-block replications was adopted. The main-plot treatments were five growth stages; the sub-plot treatments were application of 0 (control), 0.140, 0.280 and 0.420 kg/ha (2, 4 and 6 oz/A) picloram a.e. as potassium salt and 0.560, 1.120 and 1.680 kg/ha (8, 16 and 24 oz/A) 2, 4-D a.e. as ethyl ester.

Each sub-plot measured 3.6 x 1.8 meters and consisted of 12 rows, each

3.6 meters long. Sangaste winter rye was seeded with a tractor-pulled seed drill at the rate of 67 kg/ha on 26th August, 1966. First, pre-emergence spraying, was done on September 1, 1966. Later applications were made at 1-2 leaf stage (September 6), 4-5 leaf stage (September 16), flag-leaf stage (June 7, 1967) and early heading stage (June 19, 1967). The experiment was repeated in 1967 when seeding was done on August 28 and spraying for the first three stages was done at about the same dates in fall. Owing to very heavy wind erosion in the spring of 1968, plants were temporarily covered in the soil which made it impossible to obtain useful yield results. Some qualitative observations were, however, recorded.

The applications were in the form of a water spray at 20 gallons per acre (227 litres/ha) and were made with a power-operated compressed air-sprayer at 40 pounds per square inch using an 8001 nozzle. At the time of spraying winds were calm and no rain occurred in the next 72 hours after any spraying.

Observations on number of plants/m; plant height; number of leaves and number of tillers were taken on 5 randomly selected plants in each plot every 15 days until harvest time. Both immediate and long-term effects of each spraying on the crop growth and maturity were observed carefully. Grain yield for analysis of variance (20) was determined by harvesting duplicate random square-meter samples from every plot. Subsequent protein analysis was based on determinations of nitrogen by the Kjeldahl method using mercury as a catalyst.

RESULTS AND DISCUSSION

1. Saline Soil and Salt-tolerance of Crops

A. Greenhouse Experiments

i) Salt-tolerance of Perennial Grasses and Legumes on Miquelon Lake Soil

The dry matter yield of the various perennial grasses and legumes included in this study is presented in table 5(a). Tall wheatgrass had the best survival and yield of any of the species in the first three zones, which had the highest salt-concentration. Tall wheatgrass was followed by slender wheatgrass, pubescent wheatgrass and bromegrass. Also in relation to the survival and yield of controls (3:1:1 soil mixture), the above mentioned grasses were better than the others. Orchardgrass and timothy almost failed to survive in the first two zones. Of the two legumes alsike clover survived better than alfalfa at higher salinity levels. The lowest yield and plant height occurred in zone I soil (Table 5a, b) which had the highest pH and electrical conductivity (E.C.). Both plant height and yield increased as the pH and E.C. decreased, and were greatest in zone IV material.

Observations on the survival and height of plants were taken at weekly intervals. The data on plant height at harvest time (Table 5b) parallel the results of dry-matter yield.

Tall wheatgrass and slender wheatgrass are recommended as the most salt-tolerant of the cultivated perennial grasses grown in Prairie Provinces (21, 37). Tall wheatgrass has shown better results under wet conditions (21, 41). The soil under study had a high water-retaining capacity. We may, therefore, expect tall wheatgrass to give better response than slender wheatgrass. McKenzie et. al. (53) from their work on irrigated heavy textured saline soil in Saskatchewan reported that the best suited grasses were slender wheatgrass, bromegrass, crested wheatgrass and reed canary grass, while timothy was less tolerant. Orchardgrass has also been reported to grow very

Table 5. Salt-tolerance of perennial grasses and legumes in greenhouse experiments using field soil from Miquelon Lake-shore.

(a) Dry matter gm/pot (means of 2 replications)

Species	Zones *					
	I	II	III	IV	V	Control **
Tall wheatgrass	0.61	0.64	0.84	1.07	1.01	3.16
Slender wheatgrass	0.18	0.46	0.55	0.74	0.64	2.89
Pubescent wheatgrass	0.27	0.43	0.45	1.47	1.28	4.71
Bromegrass	0.21	0.65	0.76	1.25	1.14	4.55
Reed canarygrass	0.17	0.46	0.74	1.16	0.94	3.94
Intermediate wheatgrass	0.16	0.31	0.54	0.92	0.84	4.32
Orchardgrass	0.08	0.17	0.33	1.11	1.02	5.69
Timothy	0.05	0.07	0.16	1.04	0.95	5.02
Alsike clover	0.20	0.37	0.64	1.20	1.08	3.15
Alfalfa	0.12	0.41	0.52	2.03	1.33	5.77

(b) Height in cm. (means of 2 replications)

Tall wheatgrass	23	25	26	29	27	41
Slender wheatgrass	21	21	23	27	25	34
Pubescent wheatgrass	14	16	19	23	22	37
Bromegrass	14	19	20	22	21	28
Reed canarygrass	13	14	17	22	19	27
Intermediate wheatgrass	11	15	18	22	19	33
Orchardgrass	8	13	13	17	15	25
Timothy	4	10	13	14	13	24
Alsike clover	8	11	12	20	17	23
Alfalfa	7	10	11	15	13	25

* - Zone I nearest the lake, Zone V farthest back.

** - Standard 3:1:1 soil mixture.

poorly in wet-saline soil conditions (76). These reports are in agreement with the work reported here.

Alfalfa and alsike clover have been reported as resistant forage legumes for saline soils (21) but work has also indicated that these legumes and alsike clover in particular, are susceptible to sulphate salts (59). Soil analysis (Table 2) shows that the first three zones had a very high sulphate content and this may be part of the reason for poor performance of alsike clover in this soil.

ii) Salt-tolerance of Cereal Crops on Miquelon Lake Soil

Among the four cereal crops tested oats were the most tolerant to salts in all the five zones followed by barley. Winter rye and spring wheat grew almost as well as one another (Fig. 2). The crop yields were the lowest in Zone I, having the highest pH and E.C. but increased in association with decreasing pH and E.C. Height of plants showed a pattern very similar to yield, although differences were less prominent (Table 6). Observations on number of leaves per plant showed no particular difference between the zones. A photograph three weeks after seeding shows the differences between the crops and the zones (Fig. 3).

Table 6. Plant height (in cm) for cereal crops under greenhouse conditions on Miquelon Lake-shore soil of different salinity levels. (Data means of 3 replications).

Zones *	Winter rye	Wheat	Barley	Oats
I	9	18	20	24
II	11	20	21	26
III	15	25	23	29
IV	20	29	26	32
V	19	26	24	30
Control**	29	31	30	34

* - Zone I nearest the lake, Zone V farthest back.
** - Standard 3:1:1 soil mixture.

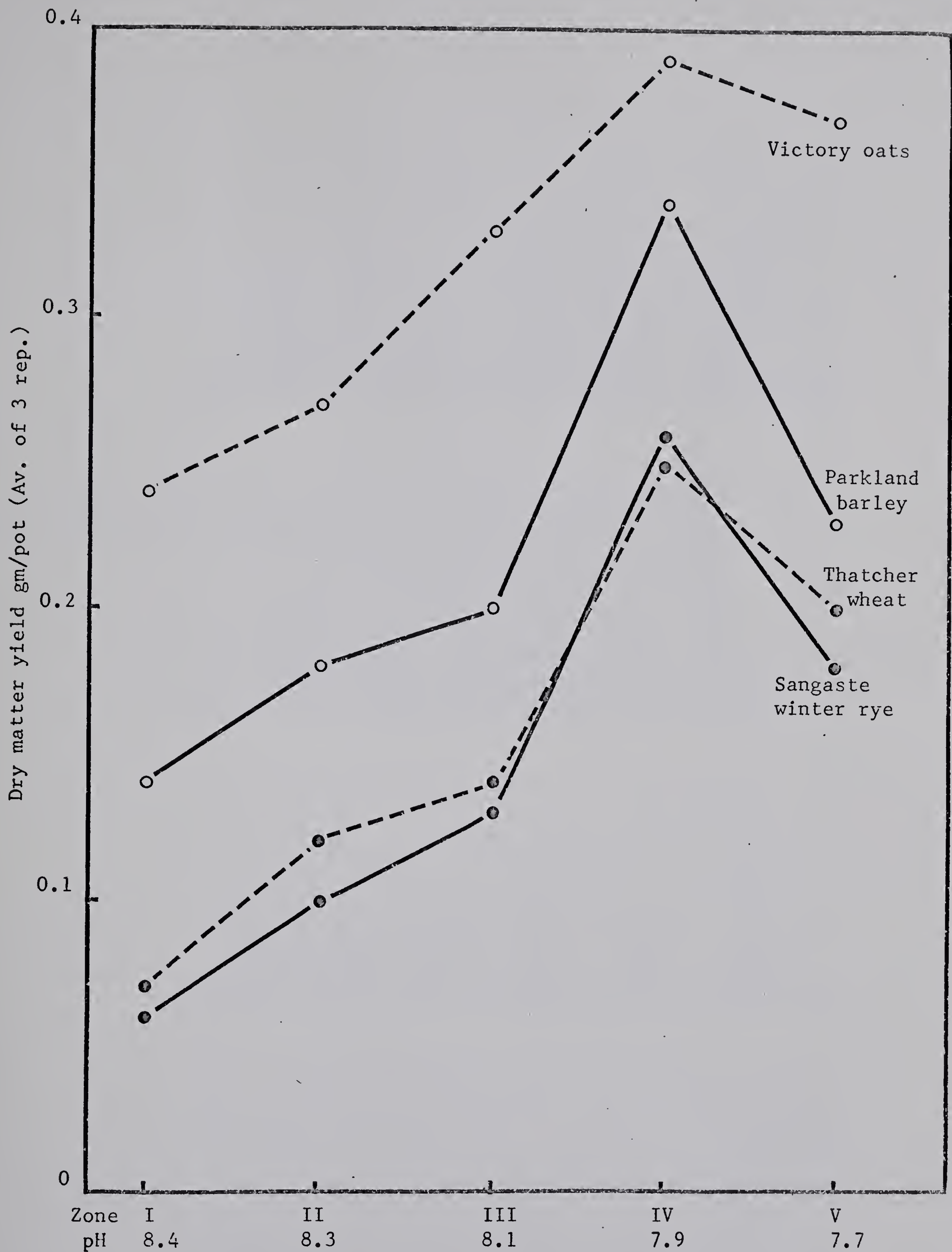
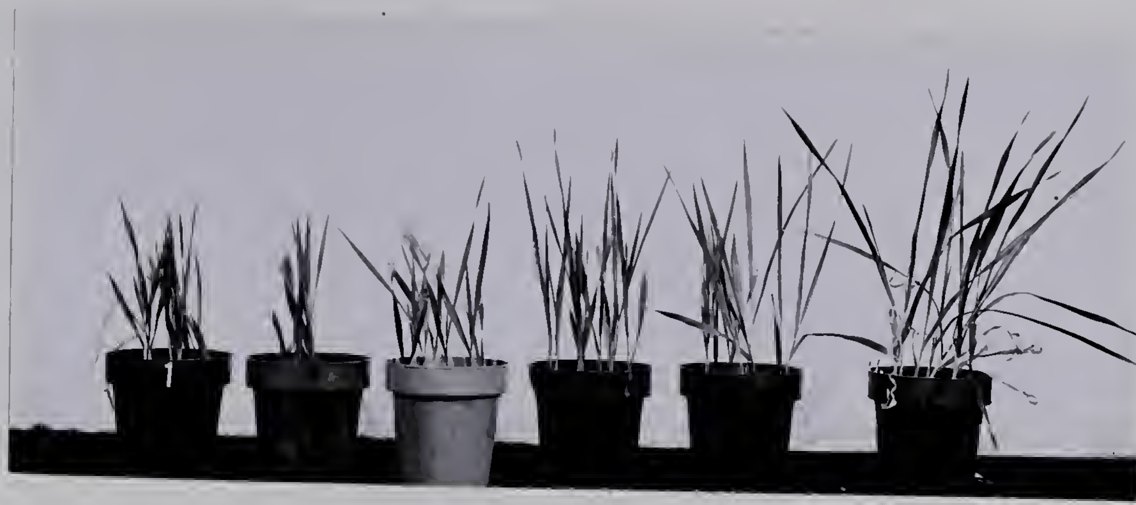


Fig. 2. Dry matter yield of cereal crops in the greenhouse on soils of different zones from Miquelon Lake-shore.

Fig. 3. Responses of barley (1); oats (2); spring wheat (3); and winter rye (4) on Miquelon Lake soil under greenhouse conditions. In each figure from left to right - zones I, II, III, IV, V and control (3:1:1 soil mixture).


1
3


2


3


4

Although both soil pH and E.C. were lowest in zone V (Table 2), the highest yield was obtained from zone IV. This could be explained partly on the basis of textural differences in the soils of two zones. The soil in zone V had a much higher percentage of sand and a very low proportion of silt and clay (Table 3). Zone IV soil had an E.C. of 5 mmhos/cm, which though harmful for susceptible crops, is considered not to seriously affect the growth of cereal crops (6). Zone V provided a better medium for crop growth as far as salinity was concerned, but its poor texture hindered vigorous crop growth.

Most of the work, in general, supports barley as the crop best suited for saline soils (5, 6, 7, 30, 70). However, oats have sometimes been reported to do as well or even better than barley depending upon the prevailing conditions. Ballantyne (6) reported barley to be the most tolerant to saline soils on brown and dark brown soil zones in Saskatchewan. In the black soil zone, however, oats were as tolerant as barley. Work in the irrigated heavy textured saline soils of Saskatchewan (53) showed oats, sorghum and millet to be tolerant, while wheat, barley, rye, flax and sweet-clover were found unsuitable. These reports are in accordance with the results reported here, where oats were more tolerant than barley. This discussion is extended with some additional references in the relevant section of field experiments.

iii) Response of Cereal Crop Varieties on Miquelon Lake Soil.

Two varietal trials were conducted on soils of zones I, II and IV. Data taken on dry-matter yield and plant height at harvesting are presented in table 7. Statistical analysis of the results showed some interesting differences between the varieties of cereal crops. Because of poor growth of crops in zone I, differences between the varieties did not turn out to be significant in that zone, except for oats where Glen and Abegweit

varieties were significantly superior to other two varieties of oats and to all varieties of barley, wheat and rye. Barley varieties produced more vegetative matter (wider leaves and thicker stems) in zone IV i.e. under the most suitable conditions for growth. On the whole, however, Glen and Abegweit varieties of oats showed the best tolerance to salinity followed by Husky and Gateway 63 varieties of barley. No significant difference was obtained between the above mentioned two varieties of oats or barley. Differences between the varieties of wheat and rye were not significant in any zone.

Table 7. Response of cereal crop varieties in greenhouse on soils of different zones from Miquelon Lake (Data means of 3 replications).

Crop	Varieties	Dry matter gm/pot			Plant height in cm.		
		Zone I*	Zone II	Zone IV	Zone I*	Zone II	Zone IV
Wheat	Saunders	0.37	0.66	1.93	21	24	42
	Canthatch	0.28	0.61	1.70	19	24	41
	Marquis	0.26	0.49	1.52	17	22	41
	Chinook	0.24	0.42	1.45	13	20	39
Winter rye	Sangaste	0.27	0.41	1.05	20	25	41
	Dakold	0.19	0.25	0.95	17	15	30
	Antelope	0.18	0.23	0.81	16	15	28
Spring rye	Prolific	0.22	0.29	0.95	19	19	32
Barley	Husky	0.62	1.12	3.51	29	32	49
	Gateway 63	0.56	1.10	2.95	26	29	47
	Betzes	0.54	0.85	2.42	23	29	42
	O.A.C. 21	0.40	0.71	2.30	21	27	42
Oats	Glen	0.86	1.89	2.82	36	42	58
	Abegweit	0.71	1.81	2.62	33	40	52
	Eagle	0.65	1.36	2.60	31	36	50
	Garry	0.54	1.33	2.58	29	35	46

L.S.D. (P = 0.05) 0.27 gm.

* - zone I nearest the lake.

As the results of first trial on the salt-tolerance of cereal crops suggested, oats once again, showed the best response and produced highest dry matter yield followed by barley. The difference between spring wheat and winter rye was not clearcut, however, wheat seemed somewhat more tolerant than winter rye on the particular soil under study.

In an effort to confirm the results and to select one particular variety of each of oats and barley for field experiments the following summer, a third varietal trial with Glen and Abegweit oats and Husky and Gateway 63 barley was conducted under controlled conditions in a growth chamber. Soil of zone II and zone IV was used in 15 cm-diameter plastic pots. The dry matter and grain yields obtained from each pot are presented in table 8.

Table 8. Response of barley and oat varieties to Miquelon Lake soil in growth chamber conditions (Data means of 3 replications).

Crop	Varieties	Dry matter yield gm/pot		Grain yield gm/pot	
		Zone II*	Zone IV	Zone II*	Zone IV
Barley	Husky	4.89	7.65	0.12	2.85
	Gateway 63	4.17	7.33	0.06	2.66
Oats	Glen	7.24	14.99	2.42	3.33
	Abegweit	6.78	13.98	2.05	2.77
L.S.D. (P = 0.05)		0.76 gm		0.29 gm	

* - zone II closer to the lake.

Statistical analysis of the dry matter and grain yields indicated that oats produced significantly higher forage and grain in soil of both zones as compared with barley. The results of earlier varietal trials (Table 7)

suggested that barley produced more vegetative growth in zone IV, i.e. under the favorable conditions of growth, as compared to oats. It seems likely , however, that if plants are grown to maturity, oats may surpass the barley even with respect to forage production. It was interesting to note that barley varieties almost failed to produce any grain in the soil from zone II, whereas oats gave appreciable grain yields.

Difference between the two varieties of barley in the two zones was still not significant. Nevertheless, within the zones Husky variety, once again, was slightly better than Gateway 63. Glen variety of oats gave significantly higher grain yields in both the zones than Abegweit, although forage production was not different in zone II. Fig. 4 illustrates these differences between the varieties. On the basis of these results Glen variety of oats and Husky variety of barley were selected for field experiments for the next summer.

Marshall (49) after working with different varieties of barley, wheat and oats in saline soils of Saskatchewan reported that the variety experiments were only slightly encouraging. Bernstein (7) states that varieties of any crop are usually so similar in salt-tolerance that varietal differences could be ignored in most crops. Among some crops, however, significant varietal differences do occur. Work at United States Salinity Laboratory showed that among the thirty varieties of barley tested, there were significant differences between some of the varieties. California Mariout was the most tolerant and Arivat, the most sensitive (4, 5). Varietal differences with regard to salt-tolerance have also been reported in cotton, many grasses and forage crops (4, 7, 70).

iv) <u>Response of Cereal Crops to Fertilizers on Miquelon Lake Soil</u>

The first fertilizer trial included the four cereal crops and only one fertilizer viz-16-20-0 at three rates of application - 0, 28 and 56 kg N/ha

Fig. 4. Response of cereal crop varieties to saline soil of Miquelon Lake (zone II, pH 8.3) in a growth chamber. From left to right - Husky and Gateway 63 (barley) and Glen and Abegweit (oats).

(0, 25 and 50 lb N/A), and two times of application - at the time of seeding and at one leaf stage (one week after seeding). At the time of seeding, fertilizer was placed about ¼" below the seed, while at one leaf stage it was applied to the soil surface on the pots. Soil of zone II only was used for this trial.

The dry matter yield obtained from each pot is presented in Fig. 5, which clearly demonstrates that crop yields increased with additional doses of nitrogen up to 56 kg/ha. No differences were attributable to the time of application.

In a second trial three fertilizers were tested on the four cereal crops at a single rate of 56 kg N/ha. The granular fertilizers viz. 13-13-13 and 16-20-0 were applied below the seed at the time of seeding while 21-21-21 was dissolved in water and applied in solution form one week after seeding. Soils of zone II and zone IV were used for this trial. The dry matter yield and plant height measured at harvest time are presented in table 9.

Statistical analysis of the results indicated that in soil of zone IV, application of 56 kg N/ha gave significant increases in the yield of all crops as compared to control, irrespective of the source of nitrogen. In soil of zone II, however, significant yield increases were obtained only for barley and oats and only when nitrogen was applied through 16-20-0. Yield increases of wheat and winter rye were not significant and these lower increases may be due to the poor growth and vigor of these crops which rendered them unable to take full advantage of the applied nitrogen. Although differences were not as sharp, plant height followed the same trends observed for dry matter yield (Table 9).

A separate trial was conducted in a growth chamber with barley and oats to help form an opinion concerning the most suitable fertilizer to be used

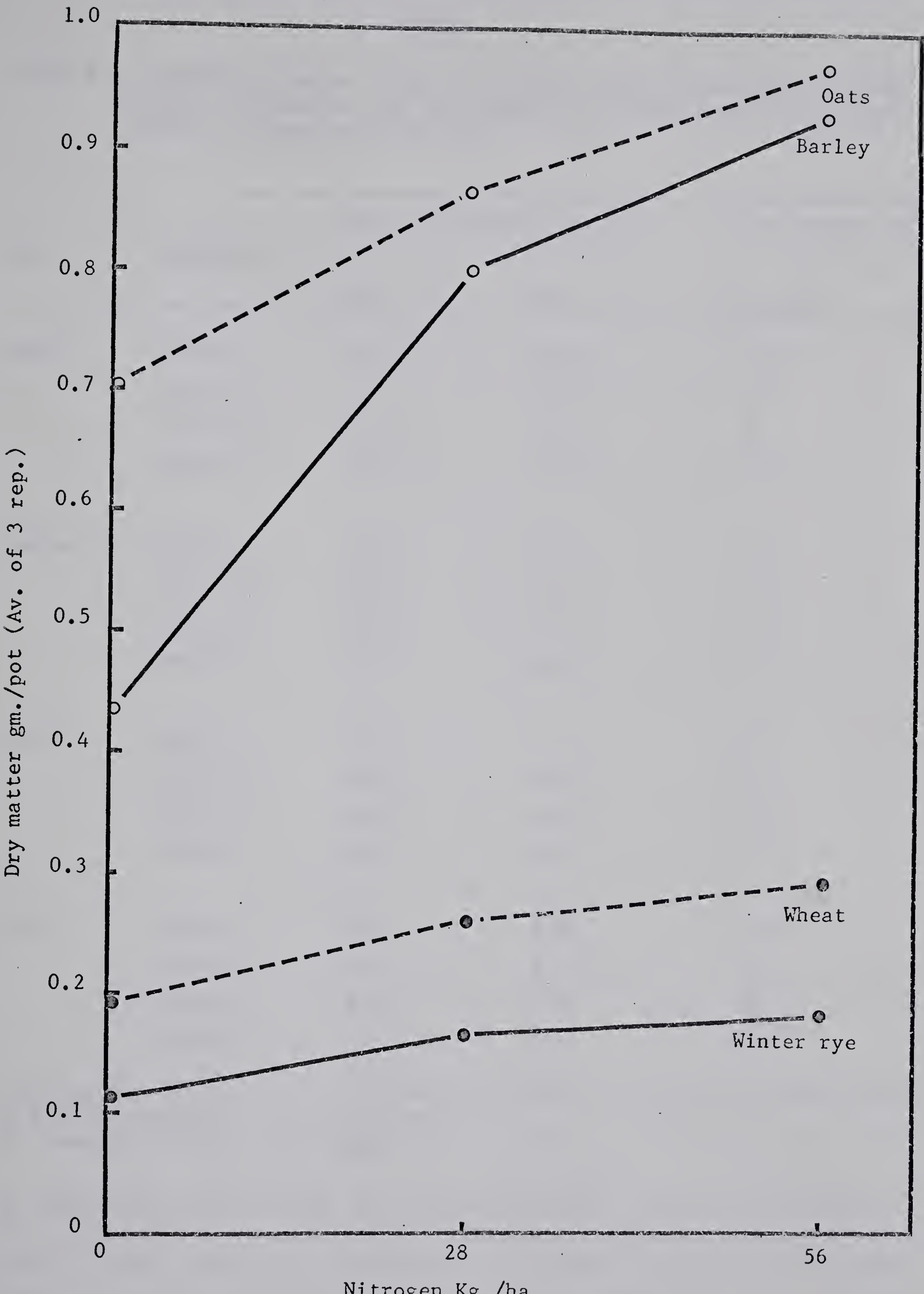


Fig. 5. Response of cereal crops to fertilizer (16-20-0) on saline soil from Miquelon Lake-shore (zone II, pH - 8.3) in the greenhouse.

Table 9. Response of cereal crops to various fertilizers (each at 56 kg N/ha) on Miquelon Lake soil under greenhouse conditions (Data means of three replications).

Crop	Fertilizer	Dry matter yield gm/pot		Plant height in cm.	
		Zone II*	Zone IV	Zone II*	Zone IV
Wheat	Control	0.28	0.72	14	34
	13-13-13	0.35	1.18	19	40
	21-21-21	0.42	1.27	21	42
	16-20-0	0.47	1.60	23	45
Winter rye	Control	0.22	0.79	15	36
	13-13-13	0.36	1.44	19	42
	21-21-21	0.38	2.10	20	44
	16-20-0	0.41	2.48	22	49
Barley	Control	0.35	1.55	20	35
	13-13-13	0.66	1.91	24	41
	21-21-21	0.69	2.17	25	44
	16-20-0	0.73	2.61	29	48
Oats	Control	0.41	1.68	30	42
	13-13-13	0.61	2.19	32	54
	21-21-21	0.74	2.21	34	56
	16-20-0	0.77	2.69	38	58

L.S.D. (P = 0.05) 0.35 gm.
* - zone II closer to the lake.

in field experiments during the following summer. Since in the earlier test nitrogen doses up to 56 kg/ha gave continuous increases in the yield (Fig. 5) a dose of 112 kg N/ha (100 lb/A) was used in this trial. Soils of zone II and zone IV were used in 20 cm.-diameter pots. The dry matter yield obtained from this trial (Table 10) suggests, once again, the beneficial

effects of fertilizers and the superiority of 16-20-0 over other fertilizers used. It seemed that a dose of nitrogen up to 112 kg/ha could be applied profitably.

Table 10. Response of barley and oats to various fertilizers (each at 112 kg N/ha) on Miquelon Lake soil in a growth chamber (Data means of 3 replications).

Crop	Fertilizer	Dry matter yield gm/pot	
		Zone II*	Zone IV
Barley	Control	1.07	1.72
	13-13-13	1.44	4.30
	21-21-21	1.63	4.74
	16-20-0	2.06	5.12
Oats	Control	1.48	2.06
	13-13-13	2.03	5.11
	21-21-21	2.42	5.43
	16-20-0	2.73	5.82

* - zone II closer to the lake.

The results of all the fertilizer trials support the conclusion that application of fertilizers could increase the crop yields 2-3 fold. There seemed to be an appreciable difference between the different fertilizers. One of the possible reasons for lower increases in crop yields after application of the same doses of nitrogen through 13-13-13 or 21-21-21 than from 16-20-0 might be that the former two fertilizers have equal proportions of the three major nutrients, N, P and K. The results of the soil analysis (Table 3) show that the particular soil under study was very poor in nitrogen and phosphorus but had quite high amounts of potassium. Application of the above two "complete" fertilizers may, therefore, upset the nutrient balance

by adding more K to the soil. A fertilizer like 16-20-0 or 11-48-0, on the other hand, may turn out to be more beneficial by increasing the level of nitrogen and phosphorus while the level of potassium remains the same, thus increasing the availability of nutrients.

It can also be pointed out from the above results that the proportionate increase in the crop yield by application of fertilizers depends largely on the performance of the particular crop on the soil. A crop like barley or oats which shows more salt-tolerance and is able to produce good yields on the saline soil shows more percent increase in yield from the addition of fertilizers. Crops like wheat and winter rye, on the other hand, because of their poor growth and vigor on saline soils do not equally respond to the added fertilizers. There even seems to be a difference between barley and oats. Because of their better salt-tolerance oats showed more reponse and relative increase in yield as compared to barley (Fig. 6).

An important point from the results of fertilizer experiments is that the relative increases in crop yields from fertilizer application decreased usually with increasing salinity levels (Tables 9 and 10). A possible explanation is that at higher salinity levels, the major limiting factor is the concentration of soluble salts while at lower salinity levels growth is restricted by both the concentration of soluble salts and the low supply of available nutrients. In the former case addition of nutrients would not be expected to give much beneficial effect; whereas in the latter case addition of nutrients might be expected to have a greater beneficial effect.

Fig. 6. Effect of 112 kg. N/ha (100 lb/A) from 16-20-0 fertilizer on barley and oats grown on Miquelon Lake soil (zone IV, pH 7.9) in a growth chamber. From left to right - barley - 0 (control) and 112 kg N/ha; oats - 0 (control) and 112 kg. N/ha.

The improvement of the fertility status of saline and alkali soils by application of fertilizers is of vital importance. It has been recognized that saline and alkali soils, like other soils of arid regions, usually respond markedly to nitrogen and phosphorus fertilization provided the drainage is good and salinity is not extremely severe. Adequate fertilization after the removal of excess soluble salts is usually required to obtain maximum productivity. Significant increases in the yield of cereal crops by fertilizer application on saline soils have been reported by various workers (9, 19, 45). A deficiency of readily available phosphorus has been recognized at higher pH (14) and higher plant response to phosphorus (as percentage of control) has been found on moderately saline than on non-saline soil (19). Among the different forms of nitrogen applied to barley grown on alkali solonetz soils at Vegreville, Alberta, organic nitrogen was found less effective than nitrate nitrogen and the more available the form of nitrogen, the greater was the effect on productivity (10). Nitrogen applied in the ammoniacal form was slightly less effective than that applied in the nitrate form in the early crops, but was on the average as effective as any form. However, in an experiment by Ferguson et. al. (19) differences among the three fertilizer formulations (11-48-0, 15-39-0, and 23-23-0) were not found significant.

B. Field Experiments

i) Growth of Perennial Grasses and Legumes on Saline Soils at Miquelon Lake

Two years work with a number of cultivated perennial grasses, including Orbit variety of tall wheatgrass, and the two legumes showed that none of these grasses or legumes were able to survive in the first two zones i.e. at higher salinity levels (experiments in the field were conducted only in zone I and zone II). Greenhouse trials (Table 5) suggested that at least

two or three of the several grasses tried could be successfully grown on this soil. The results under field conditions were, however, much less promising. In 1966 some of these species germinated on the rototilled areas only, and lived for a short time, but it was surprising to see that in 1967 most of them did not even emerge.

As discussed earlier, tall wheatgrass, slender wheatgrass and Russian wild rye-grass have been reported as the most salt-tolerant of the cultivated perennial grasses and recommended for saline soils in the Prairie Provinces (21, 37, 64). Orbit variety of tall wheatgrass developed at Swift Current, Saskatchewan, and licenced in 1966 has shown considerable adaptation to wet saline soils in Canada (41). Both tall wheatgrass and slender wheatgrass gave good growth on Miquelon Lake soil in the greenhouse conditions, which can be ascribed partly ~~due~~ to the possible leaching of salts with water from the pots in the greenhouse. This might be coupled with the fact that in the greenhouse watering was done as necessary and thus there was no free water-table. In the field, on the other hand, the first two zones near the lake-shore, where these experiments were conducted, had very high water-table particularly in the spring (Table 4). Dodd *et. al.* (17) working on the saline soils of Saskatchewan reported that on the Saline Gleysol soils (average pH - 8.1 and E.C. - 15.2 mmhos/cm) production of even the more salt-tolerant cultivated grasses would not prove feasible because these species do not tolerate the extended periods of flooding, characteristic of that habitat. The results obtained here seem to be in agreement with the findings of these workers.

ii) Growth of Winter Rye on Saline Soils at Miquelon Lake

Three weeks after seeding, the winter rye had emerged well although the stand was not uniform, particularly in zone I i.e. nearest the lake,

where plants grew only in patches (Table 11a). There was no pronounced difference between the first three zones, which had high salinity levels. Best growth, as in other experiments, was obtained in zone IV followed by zone V. It was noticed that plants in the first three zones, soon after germination, began turning pinkish and growth was very poor while zone IV and zone V had much healthier and green plants. Figure 7, a photograph along the strip on September 22nd, about a month after seeding shows the weak and dark pink color plants in the first three zones.

Early the following spring it was found that none of the plants survived in the first three zones. Growth was satisfactory, however, in zone IV and zone V. Zone IV had greater number of plants/m^2; taller and healthier plants and higher dry matter and grain yield as compared with zone V (Table 11b). Some possible reasons for the superiority of growth in zone IV in the field are discussed in section (iii) of field experiments. In the part of the strip where rye was seeded without cultivation, a few plants were present only in zone IV.

Table 11. Growth of winter rye on saline soil at Miquelon Lake. (Data means of 3 replications)

(a) Observations on September 15, 1966.

Zones*	Number of plants/m^2 in sparsest area	Number of plants/m^2 in densest area	Average plant height in cm	Average number of leaves/plant
I	0	43	6	2
II	7	97	7	3
III	16	128	8	4
IV	61	248	13	6
V	35	203	10	5

Table 11. (Continued).
(b) Observations at harvest time (August 8, 1967).

Zones	Number of plants/m^2	Height in cm.	Dry matter yield gm/m^2	Grain yield gm/m^2
IV	22	113	282.3	92.7
V	17	98	211.0	43.3

* - zone I nearest the lake, zone V farthest back.

The literature about the salt-tolerance of rye is not very definite. Bernstein (7) reports that rye could be grown in a soil with an E.C. of 8 mmhos/cm with only small losses in yield. Work at United States Salinity Laboratory (70) shows that in a soil with an E.C. of 8-10 mmhos/cm, 50 percent decrease could be expected in the yield of rye. However, so many different combinations of salts occur in saline soils that it is hard to settle upon a salt-concentration concerning which it can be stated that a crop will grow without much reduction in yield. In the present study the average E.C. in the first three zones varied between 8.4-10.9 mmhos/cm (Table 2). From the results of this experiment it seems that winter rye could hardly grow satisfactorily in soils having an E.C. of above 8 mmhos/cm. Reasonable yields can, however, be obtained from the soil having E.C. of 5 mmhos/cm. These results do not give any idea about the performance of winter rye for E.C. values between 5-8 mmhos/cm.

iii) Growth of Barley and Oats on Saline Soil at Miquelon Lake.

The most suitable varieties of barley and oats (Husky and Glen respectively) selected on the basis of the greenhouse trials, were grown in strips extending back from the lake-shore. Results were very similar to those obtained in the greenhouse in that oats, on the whole, were superior to

Fig. 7. Performance of winter rye in the saline soil of Miquelon Lake. In the left background the photograph shows the very poor growth and discoloration of plants which failed to survive the winter in the first three zones of higher salt-concentration near the lake-shore.

barley (Table 12). The dry matter and grain yields of barley were higher than for oats only in zone IV i.e. under the most suitable conditions for growth, but declined sharply at higher salinity levels. Fig. 8 shows a clear line of demarcation after which growth of barley was very stunted. This demarcation line was at the point where zone III started. Oats, on the other hand, continued to grow even beyond this line and grew, although poorly, very close to the lake-shore.

Table 12. Response of barley and oats to saline soil at Miquelon Lake (Data means of 3 replications)

Zones*	Plant height in cm		Dry matter gm/m^2		Grain yield gm/m^2	
	Barley	Oats	Barley	Oats	Barley	Oats
I	8	26	4.0	31.3	0	3.7
II	16	30	14.3	63.0	0	13.3
III	9	22	10.3	44.7	0	9.0
IV	42	59	551.0	435.7	203.3	164.0
V	27	37	136.0	159.3	37.0	47.0

* - zone I nearest the lake, zone V farthest back.

As far as salinity was concerned, the first three zones had a salt concentration high enough to interfere seriously with the crops. Oats produced higher dry matter as compared to barley in all the zones except ~~that of~~ zone IV. The dry matter production increased significantly for oats, with decreasing pH and electrical conductivity, in the first three zones. For barley, however, there were no significant differences among the first three zones. Height of oats was significantly more than barley in all the zones and oats also had more plants/m^2.

Results in the greenhouse showed that barley produced a very small

Fig. 8. Cereal crops on saline soil at Miquelon Lake. A line of demarcation extends from the middle foreground (white stakes) toward the background. To the left is zone III and to the right is zone IV. Oats (second strip from the front) unlike barley produced some grain in zone III and beyond into zone I.

amount of grain in soil of zone II (Table 8). Under field conditions, however, barley failed to produce any seed in the first three zones. Oats did produce a limited amount of grain in each of these three zones (Table 12).

Among the five zones, yields of both crops were lowest in zone I which had the highest pH and E.C. of saturation extract, and increased as pH and E.C. values decreased. A decline in the yield was again noticed on zone III over zone II, which could be attributed mainly to the very heavy infestation of Canada thistle and sow thistle competing with the crops. In agreement with greenhouse results, higher yield was obtained from zone IV followed by zone V. In spite of lowest pH and salt-concentration (Table 2), zone V produced lower yields than zone IV which, as discussed earlier (section (ii) of greenhouse experiments), might be attributed partly to the poor soil texture of zone V (Table 3). An additional reason for the poor growth in zone V, under field conditions, may be the competition of baltic rush which forms about 60% of the natural vegetation in this zone. Baltic rushes have a very competitive deep and spreading root system.

As discussed earlier in section (ii) of greenhouse experiments, most of the work indicates barley as the most salt-tolerant crop. However, there have been some reports that oats do as well or even better than barley depending upon the conditions (6, 38, 53). As discussed in U.S.D.A. Handbook No. 60 (70) climatic conditions may influence profoundly the reaction of plants to salinity. Some possible reasons for the better performance of oats in our experiment seem to be the heavy soil texture, wet conditions and high water-table of the soil. Work on irrigated heavy textured saline soils of Saskatchewan (53) showed oats as the most tolerant to salts whereas barley was found unsuitable. Klages (38) reports that oats do better on cold, wet soil than other cereals. According to Mackie (47), "alkali and saline soils may, if the climatic conditions are favorable, produce a crop of oats where

wheat and barley would fail". These investigations, in line with the present research, support the idea that on wet saline soils oats may show better salt-tolerance than barley.

iv) Crop Response to Fertilizers on Saline Soils at Miquelon Lake

In addition to ammonium phosphate (16-20-0) which appeared to be the fertilizer best suited to saline soils based on greenhouse results (Tables 9 and 10), ammonium sulphate (21-0-0) was included in the field tests at Miquelon Lake. Ammonium sulphate is said to increase the soil acidity by decreasing the pH of the soil. Application of 112 kg N/ha through either of the two fertilizers increased the yield of both barley and oats (Table 13). Similar to the greenhouse results, increases in yield in the field were less in zone I i.e. at higher salinity levels, than in other zones. Some possible explanations for the lower yield increases at higher salinity levels have been discussed in section (iv) of greenhouse experiments.

Table 13. Response of barley and oats to fertilizers (each at 112 kg N/ha) on saline soil at Miquelon Lake (Data means of 3 replications)

Zones	Fertilizers	Height in cm.		Dry wt. gm/m^2		Grain yield gm/m^2	
		barley	oats	barley	oats	barley	oats
I*	Control	6	20	5.3	16.0	0	4.1
	21-0-0	8	26	6.4	28.1	0	10.0
	16-20-0	9	33	7.9	41.2	0	14.8
II	Control	20	30	25.0	84.3	0.4	20.3
	21-0-0	25	49	41.8	210.5	9.3	55.6
	16-20-0	29	60	67.2	358.2	12.9	83.0

* - zone I nearest the lake.

The relative increases in yield were higher for oats in both zones as compared with barley. As discussed earlier, the crop which shows maximum salt-tolerance, should be expected to make better use of added nutrients. Oats showed more increase in the number of plants/m^2; the height of plants; dry matter yield and grain yield resulting from the application of fertilizers. A visible beneficial effect of fertilizers on barley was that in zone II barley produced significantly larger amounts of grain compared to control plots.

Ammonium phosphate (16-20-0) proved better than ammonium sulphate (21-0-0) at the same levels of nitrogen. A simple reason seems to be that 16-20-0 supplies phosphorus, in addition to nitrogen, both of which are present in very small amounts in the soil (Table 2). Experiments on saline soils in Saskatchewan (45) showed that either high nitrogen or high phosphorus rates resulted in significant yield increases. Highest yields, however, were obtained with high rates of nitrogen and phosphorus in combination (each at 100 lb/A). In our experiments both greenhouse and field results indicated that 16-20-0 would be the most suitable fertilizer for saline soils which are rich in potassium. The greenhouse results have been discussed earlier. In both greenhouse and field tests a dose of 112 kg N/ha seemed to be adequate, but will vary depending upon the amount of nitrogen present in the soil.

In general, however, it seems obvious that under the conditions of these field experiments added fertilizers, although producing some measurable improvement, did not bring about a worthwhile beneficial effect to overcome the adverse influence of the poor soil condition.

2. Cropping, Mowing and Discing for Control of Canada thistle (*Cirsium arvense*)

The number of Canada thistle shoots/m^2 and height of the weed decreased significantly when growing in competition with winter rye. A significant reduction was also noticed in the dry matter of thistles at harvesting time (Table 14). Although none of the treatments controlled thistles completely, mowing followed by discing was significantly better than two repeated mowings.

Table 14. Effect of mowing and discing with and without winter rye competition on control of Canada thistle on black loam soil at Ellerslie. (Data means of 3 replications)

Treatments	Canada thistle			Winter Rye	
	Shoots/m^2	Height in cm.	Dry weight kg/ha*	Height in cm.	Grain kg/ha*
Control - weed free	--	--	--	151	3140
Seeded - Mowing and discing	15	58	1030	150	3090
- Mowing and mowing	26	62	3440	147	2970
Not seeded - Mowing and discing	41	64	5930	---	----
- Mowing and mowing	55	67	9660	---	----
L.S.D. (P = 0.05)	5.1	1.1	2295	1.4	72

* - kg/ha x 0.892 = lb/A.

Because of the poor control of Canada thistle by two mowings, height of the rye plants and grain yield for the treatment were significantly reduced as compared to control. Both the grain yield and height of rye plants, when thistles were controlled by mowing and discing, were not significantly less than for the weed-free control (Table 14). The number of rye plants per meter row and tiller number also showed trends similar to grain yield and plant height.

It can be concluded that a greater reduction in weed population and growth was obtained by mowings combined with cropping than by mowings alone.

Lee (43) found that clipping or mowing Canada thistle once a year in the early bud stage prevented seed development, but did not eradicate the plants. However, frequent clipping in combination with a good smother crop helped reduce and weaken the stand. Similar results have been reported by Hodgson (33) and Derscheid et. al. (16). The general indication is that within a given period of time use of some competitive crop with mowing or cultivation gives better and earlier control of Canada thistle than cultivation or mowing alone.

Many reports indicate that Canada thistle can readily and economically be eradicated by seeding infested land to forage crops (33, 43, 50, 66, 68). Certain forages seem to be more competitive than others when combined with mowing. Alfalfa has been considered as an effective competitor of Canada thistle because of its vigorous growth habit and rapid recovery after mowing (16, 32, 50, 66). Autumn-sown cereals compete effectively with Canada thistle, whereas spring-sown cereals usually encourage its spread (33). Little emphasis has been given to winter rye as a smother crop but it seems to be a very effective competitor with Canada thistle because of its early growth in the spring. By the time thistle plants appear in spring, winter rye has already resumed growth to compete with the thistles for water, light and nutrients. The present work supports the view that winter rye in combination with mowing and/or cultivation before seeding can at least effectively reduce, in good soil in the Edmonton region, dense stands of Canada thistle and prevent them from having any appreciable effect on grain yield.

3. <u>Effect of Seeding Dates and Clipping on Winter Survival of Winter Wheat and Winter Rye</u>

All of the 1967 seedings of winter wheat and winter rye produced only vegetative growth during the same year. Observations early in spring

(May 23, 1968) showed that the crop resulting from seeding on June 14, 1967, without subsequent clipping, suffered extensive winter killing (Table 15). The survival of unclipped rye plants was slightly less than it was for winter wheat (Table 15, Fig. 9). Plants of the June 14 seeding clipped once later on different dates were, on the other hand, able to maintain a good stand irrespective of the clipping date. For the July 25 and August 28 seeding dates, however, control plots with no clipping produced a crop stand similar to that of the clipped ones.

Table 15. Effect of seeding dates and clipping on crop stand and number of tillers of winter wheat and winter rye sown on black loam soil at Ellerslie (Data recorded on May 23, 1968, mean of 3 replications)

Seeding	Clipping	No. of Plants/m[b]		No. of Tillers/plant	
Date	Date	Wheat	Rye	Wheat	Rye
June 14	Control[a]	2	1	5[c]	6[c]
	July 25	6	6	6	7
	August 28	6	6	6	7
	September 15	6	6	6	7
July 25	Control[a]	6	6	6	8
	August 28	7	6	7	8
	September 15	7	6	7	8
August 28	Control[a]	7	7	8	8
	September 15	7	7	8	8

a - Not clipped for forage.
b - Means of 5 randomly selected meters per plot.
c - Number of tillers on dead plant, all other data for live tillers.

It was suspected that clipping might have been helpful in plant survival possibly by increasing the number of tillers in the clipped plants. Counts made on number of tillers of both surviving and dead plants early in

Fig. 9. Sangaste winter rye (top) and Kharkov 22 MC winter wheat (bottom) seeded on June 14, 1967, photographed July 3rd, 1968. Six rows in the middle of top photograph and six rows, between the two stakes, in the middle of bottom photograph are the unclipped controls showing extensive winter killing. Healthy plants on the left and right had been clipped on different dates in 1967.

spring (Table 15) suggested that although clipped plants from the June 14 seeding had slightly more tillers as compared to unclipped plants, the differences were not appreciable. There appears, therefore, to be some other physiological factor or factors responsible for this differential response perhaps associated with the relative senescence of the undisturbed plants of the earliest seeding.

As would be expected, the forage yields for both crops increased as the length of time between seeding and clipping times increased (Table 16). Plants seeded on June 14 and clipped on September 15 produced the highest forage yield whereas those seeded on August 28 and clipped on September 15 resulted in the least amount of forage. Winter rye produced more forage at each clipping than did winter wheat. Reports from various other investigations (34, 55, 67, 72) also indicate that winter rye produces more forage than either wheat or oats.

Table 16. Plant height at maturity, forage and grain yields of winter wheat and winter rye after various seeding date and clipping treatments (Data means of 3 replications)

Seeding Date	Clipping Date	Forage Yield kg/ha		Grain Yield kg/ha**		Plant Height(cm)	
		Wheat	Rye	Wheat	Rye	Wheat	Rye
June 14	Control*	----	----	860	490	95	122
	July 25	2807	3102	3090	3280	103	131
	August 28	4988	6358	2880	3200	101	131
	September 15	6033	7303	2600	2980	99	130
July 25	Control*	----	----	3020	3100	102	133
	August 28	1528	1593	3220	3350	105	136
	September 15	2486	3072	3110	3310	103	133
August 28	Control*	----	----	3690	3840	104	132
	September 15	212	363	3580	3780	104	132
L.S.D. (P = 0.05)				310	280		

* - Not clipped for forage.
** - For wheat - kg/ha x 0.015 = bu/A; for rye - kg/ha x 0.016 = bu/A.

Clipping of plants for forage had a very pronounced beneficial effect on the grain yield of winter wheat and winter rye sown on June 14 as compared with the unclipped control. No significant effect of clipping could be observed on grain yields in the later seeding dates (Table 16). As discussed earlier, the control plots not clipped for forage in the June 14 seeding had only a few surviving plants (Table 15, Fig. 9) while clipped plots had a good crop stand. The grain yields for these control treatments were also decreased by about 67% for winter wheat and 84% for winter rye as compared with the clipped plots. Thus winter wheat suffered less damage with regard to both crop stand (Table 15) and grain yield (Table 16) than winter rye when both crops were left unclipped after the June 14 seeding. This difference between winter wheat and winter rye is interesting in view of the fact that winter rye seeded in the fall is recognized to be a more winter hardy crop than winter wheat. Unexplained physiological differences between the two species seeded early in the year apparently are responsible for the difference in this relationship noted here. Unclipped plots for either crops of the later seeding dates did not suffer any significant reduction in grain yield as compared with clipped plots. Work by some of the other investigators has also shown that grazing or clipping during the fall (67) or one clipping early in spring (1, 55, 73) caused no reduction in grain yields of winter wheat and winter rye.

The earliest clipping associated with the June 14 and July 25 seeding dates resulted in slightly higher grain yields than were obtained after the later clippings. Such differences were not statistically significant except after June 14 seeding when the clipping with the highest yield of forage, on September 15, resulted in significant yield reductions for both crops as compared with clipping on July 25. However, only a month's delay in clipping,

from July 25 to August 28, of this early seeded material almost doubled the forage yield without any significant reduction in grain yield. Similar results were obtained after the July 25 seeding date when clipping was delayed from August 28 to September 15. Warren et. al. (73) reported that grain yields of Dominant winter rye, seeded in late May or early June and clipped at different times, decreased proportionately with delay in forage harvest. The results from their experiment are in partial agreement with the results reported here.

Grain yields of both winter wheat and winter rye were significantly higher after August 28 seeding as compared with early seeding dates. However, maturity of both crops was delayed by about 5 days for August 28 seeding over the earlier seeding dates. Clipping treatments did not have any effect on the maturity of either crops. Contrary to results from another investigation (73) no reduction in the height of plants due to clipping treatments was noticed at any seeding date. Even a slight increase in the height of plants seeded on June 14, appeared to result after clipping (Table 16). Sprague (67) has also reported that plant height of winter wheat and winter rye was unaffected by fall grazing.

This experiment indicates the potential value of very early seeding of winter wheat and winter rye if followed by harvesting of the forage of these crops during the year of seeding. Although there was some reduction in grain yield of the early seeded crop as compared with results from sowing at the accepted normal fall seeding time, the additional yield of forage might compensate for the reduction in grain yield. Winter rye forage has been reported to be of high quality (73) and from this standpoint both crops may be worthy of more attention. Moreover, the results may be of some benefit as a step toward better understanding of the phenomenon of winter hardiness.

4. Response of Winter Rye to 2, 4-D and Picloram Applied at Different Growth Stages on Black Loam Soil at Ellerslie

The lowest dosage of picloram (0.140 kg/ha) and of 2, 4-D (0.560 kg/ha) despite some evidence of injury, had no statistically significant effect on plant height or grain yield for any stage of treatment from pre-emergence to early heading. The higher dosages of both herbicides, however, caused a significant reduction in plant height and grain yield for all stages of treatment (Table 17).

Table 17. Effects on height and grain yield of winter rye of 2, 4-D and picloram applied at different growth stages of the crop (Data mean of 3 replications)

(a) Plant height in cm at harvest time (August 2, 1967)

Treatments		Stage of Application					
		Pre-emergence Sept. 1, 1966	1-2 leaf Sept. 6	4-5 leaf Sept. 16	Flag leaf June 17, 1967	Early head June 19	Av.
Control		146	150	150	148	149	149
Picloram -	0.140* kg/ha	143	148	144	146	145	145
	0.280 kg/ha	133	143	134	141	142	139
	0.420 kg/ha	132	143	129	139	135	136
2, 4-D	0.560 kg/ha	140	147	150	144	141	144
	1.120 kg/ha	139	146	145	139	132	140
	1.680 kg/ha	134	143	138	131	129	135

* - 2 oz/A

(b) Grain yield of rye in kg/ha (x 0.892 = lb/A)
(x 0.016 = bu/A)

Control		2990	3170	3050	3090	3210	3100
Picloram -	0.140 kg/ha	2900	2980	2860	2910	2990	2930
	0.280 kg/ha	2660	2820	2730	2810	2480	2700
	0.420 kg/ha	2570	2570	2250	2610	2290	2460
2, 4-D	0.560 kg/ha	2860	2940	2840	2930	3160	2950
	1.120 kg/ha	2670	2780	2540	2740	3040	2750
	1.680 kg/ha	2410	2520	2200	2620	2850	2520

Height L.S.D. (P = 0.05) = 7** cm
Yield L.S.D. (P = 0.05) = 330** kg

** - valid for comparisons between doses within growth stages.
L.S.D. (P = 0.05) for overall mean doses effect (Average) - for height - 5 cm; for yield - 180 kg.

Although differences between applications at different stages of rye growth were not significant, the 4-5 leaf stage (late fall application) apparently was most sensitive as indicated by smaller heads, a delay in maturity of about 5 days and various morphological abnormalities. In 2, 4-D treated material these included fused edges of sheaths, twisted leaves, protuberances at the nodes and deformed heads (Fig. 10); as a result of picloram treatments there were some "onion leaf", sterile heads and head abnormalities (Fig. 11). The 1-2 leaf stage (early fall) apparently seemed most tolerant. Qualitative observations recorded on herbicide applications at the first three stages in fall of 1967 showed results very similar to those obtained in 1966. A reduction in plant height and head and spike abnormalities described above were noted also in 1968 as a result of application of the highest doses of 2, 4-D and picloram in late fall (4-5 leaf stage), 1967.

Each increase in the dosages of both herbicides above the lowest one (which had no significant effect) gave significant yield reductions (Table 17b). Further the effect of 0.140 kg/ha of picloram was not statistically different from that of 0.560 kg/ha of 2, 4-D ester; 0.280 kg/ha of picloram was not different in effect than 1.120 kg/ha of 2, 4-D and 0.420 kg/ha of picloram was about equal to 1.680 kg/ha of 2, 4-D ester with regard to both yield and plant height reductions. Data on number of tillers per plant, number of plants per meter and length of heads followed trends very similar to those for plant height and grain yield.

Data on the effects of the chemicals on grain characteristics are presented in Table 18. Since there was no difference between the stages of treatment, the figures have been averaged for five growth stages and only means are reported.

Fig. 10. Abnormalities produced in 1967 by late fall spraying in 1966, of Sangaste winter rye (4-5 leaf stage) with 1.680 kg/ha (1.5 lb/A) 2, 4-D ester on black loam soil at Ellerslie. Right, control.

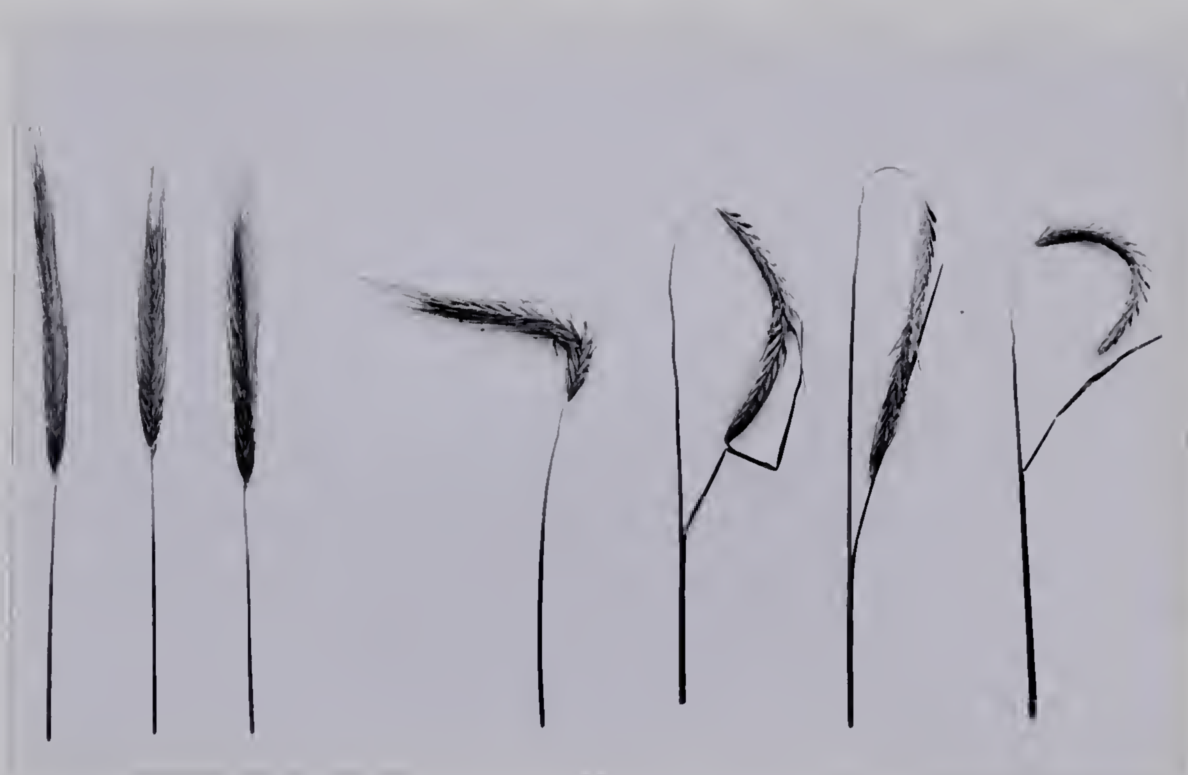


Fig. 11. Spike abnormalities in Sangaste winter rye resulting in 1967 from late fall spraying (4-5 leaf stage) in 1966 with 0.420 kg/ha (6 oz/A) of picloram (potassium salt) are shown at the right. The three heads at the left are normal (untreated).

Table 18. Effect of 2, 4-D and picloram on grain characteristics of winter rye grown at Ellerslie (average of results from treatments at 5 growth stages)

Treatments		Bushel Weight (in lb)	% Moisture	Protein		% P	% Ca
				%	kg/ha		
Control		55.6	6.5	13.5	418	0.18	0.07
Picloram -	0.140* kg/ha	54.9	6.3	13.6	396	0.19	0.06
	0.280 kg/ha	54.7	6.4	13.8	373	0.20	0.06
	0.420 kg/ha	52.9	6.6	14.0	344	0.22	0.06
2, 4-D	0.560 kg/ha	54.9	6.3	13.6	401	0.18	0.07
	1.120 kg/ha	54.5	6.4	13.7	377	0.19	0.06
	1.680 kg/ha	54.4	6.3	13.9	350	0.20	0.06

* - 2 oz/A

With the exception of the effect from 0.420 kg/ha of picloram the weight per bushel and plumpness of grain was not decreased to any appreciable extent by the application of different doses of the two chemicals. With regard to work by other investigators, no decrease in the bushel weight of wheat was noticed by Guenthner et. al. (27) after treatment at 5-6 leaf stage with 0.070 kg/ha (1 oz/A) of picloram. No particular trend of change in the present experiment, could be noticed in moisture percentage of grain, which differed only slightly from one treatment to another.

Treatments with both 2, 4-D and picloram in the present work affected the protein content of winter rye grains, which was negatively associated with yield. When yield was decreased by treatment the percentage protein content was increased (Tables 17 and 18). That increased protein content was associated with yield reductions rather than as a physiological response to the growth regulator seems fairly clear. If calculated on an hectare basis, the average production of protein per hectare of treated rye tends to be slightly less than that of control (Table 18), indicating that yield reductions

were greater than the compensating increases in protein. An increase in protein percentage of wheat after treatment with picloram (½ - 1½ oz/A) was reported by Nalewaja (57). Protein percentage of winter wheat after treatment with 2, 4-D had been reported to be inversely associated with yield by Klingman (39). When no yield changes occurred with treatment, 2, 4-D had no effect on protein content. This seems to be the generally occurring effect of such herbicide treatments.

Similar to the results for protein, a tendency toward an increase was also noticed in phosphorus percentage of grain after application of herbicides (except by 0.560 kg/ha of 2, 4-D ester). Phosphorus percentage also appeared to increase slightly in association with increasing herbicide doses.

The calcium percentage of grain may have been decreased very slightly by herbicide applications as compared with control and there appeared to be no difference between the two herbicides and their dosages.

Only limited previous work on the tolerance of winter rye to picloram herbicide has been reported. Carder (12) makes reference to this crop in an experiment involving control of the weed _Matricaria_ _maritima_ var. agrestis (Scentless chamomile). He used different herbicides including picloram (1, 2, 4 and 6 oz/A) in a field seeded to Dakold winter rye. The rye was about 10 cm tall when the herbicides were applied in spring. The yields of rye were not reported but periodic observations showed that 4 and 6 oz/A of picloram "did have a derogatory effect on the rye." No appreciable damage was caused by the lower doses of picloram. It may also be pertinent to some extent to note that Friesen _et_. _al_. (23) working on the tolerance of triticale (a synthetic grain developed from durum wheat and rye) to various herbicides reported visible injury to the crop and yield reductions by picloram (¼ oz/A + 4 oz/A of 2, 4-D). They concluded that "this crop will respond to herbicides much like wheat rather than like rye."

There is more information available concerning wheat treated with the above mentioned herbicides (25, 27, 36, 51, 57, 71) than there is for rye. Fall spraying (October 14) of 2, 4-D in winter wheat resulted in many morphological abnormalities and caused greatest injury of all stages included (39). Winter wheat was also sensitive to picloram at the rate of 0.75 oz/A when applied at the crop's 5-leaf stage (42). There seems to be a fairly close similarity in response of winter wheat and winter rye treated at comparable growth stages with 2, 4-D and picloram. On the basis of the limited available information on the effects of these herbicides on winter rye, winter wheat may be more susceptible than winter rye especially to picloram.

SUMMARY AND CONCLUSIONS

1. Experiments on Saline Soil Adjacent to Miquelon Lake

Experiments were conducted with a number of commonly cultivated perennial grasses, legumes and cereal crops both in the greenhouse and in the field on saline soil at Miquelon Lake. Although some of the perennial grasses viz. tall wheatgrass (Agropyron elongatum (Host) P.B.), slender wheatgrass (Agropyron trachycaulum (Link) Malte) and pubescent wheatgrass (Agropyron trichophorum Link) exhibited good salt-tolerance under greenhouse conditions, two years work in the field showed that none of the grasses or legumes tested would grow satisfactorily and establish themselves on the saline lake-shore. Among the four cereal crops viz. - barley, oats, wheat and winter rye; oats proved the best in both greenhouse and field tests. Although barley is considered very tolerant to salts (5, 6, 7, 30, 70), it seems that wetness of saline areas limits its use on these areas and oats will probably do better on the poorly drained saline soils. However, in so far as the objectives of the study were concerned, even the oats were not suitable enough to establish a satisfactory cover close to the lake-shore which had high water-table and very high salinity levels.

A series of tests conducted with different varieties of cereal crops in the greenhouse showed some significant varietal differences. Husky variety of barley and Glen variety of oats on the whole, were the most tolerant of the varieties tested. No significant differences were, however, obtained between the varieties of wheat and winter rye.

Work with different commercial fertilizers on cereal crops suggested that application of fertilizers could give 2-3 fold increases in crop yields. Under the conditions of field experiments, added fertilizers, although producing distinct improvement, did not bring about worthwhile beneficial effect to overcome the adverse influence of the poor soil conditions. The relative

increases in the yield of barley and oats due to fertilizer application in the greenhouse were much higher as compared to wheat and winter rye suggesting that the beneficial effects of fertilizers depend largely on the performance of a particular crop on the saline soil. Saline soils in general, have relatively high amounts of potassium and application of an nitrogen and phosphorus containing fertilizer such as 16-20-0 would give relatively higher yield increases compared to a "complete" fertilizer such as 13-13-13 or 21-21-21 at comparable rates of nitrogen. A dose of 112 kg N/ha (100 lb N/A) was found most profitable in the present experiment but would most likely vary depending upon the nutrient status of the soil.

2. Cropping, Mowing and Discing for Control of Canada thistle (*Cirsium arvense*)

Winter rye in combination with mowing and discing treatments was very effective in reducing a dense stand of Canada thistle on black loam soil at Ellerslie. Seeding of the crop after mowing of thistles in first week of August and discing late in the month reduced Canada thistle to almost 1/6th the amount where no crop was seeded. Mowing and discing treatment was three times as effective as two repeated mowings with regard to Canada thistle control. When seeded in combination with mowing and discing treatment, no significant reduction due to Canada thistle competition was noticed in the grain yield of winter rye as compared to its weed-free control. Owing to poor control of thistles the grain yield was reduced, however, in plots having two repeated mowings before seeding. The results of the experiment support the view that winter rye is an excellent competitive crop for controlling Canada thistle under Alberta conditions.

3. Effect of Seeding Dates and Clipping on Winter Survival of Winter Wheat and Winter Rye

Some pronounced differences in winter survival and yield were obtained with Sangaste winter rye and Kharkov 22 MC winter wheat seeded on fertile

black loam soil at three different dates (June 14, July 25 and August 28, 1967) and clipped at different times after each seeding date. Most of the plants of both crops seeded on June 14 and not clipped later were unable to survive the winter whereas clipped plants had an apparently normal stand. Reduction in grain yield after this earliest seeding date was more for winter rye than for winter wheat. In the later seeding dates no significant difference occurred in the grain yields of either crops due to clipping treatments. Data indicated no marked difference in the tiller number of surviving and dead plants suggesting that other factors were responsible for differential survival.

Winter rye produced more forage at each clipping than did winter wheat. Forage yield of crops seeded on June 14 and clipped on August 28 was almost double the yield of forage clipped on July 25 without any significant reduction in subsequent grain yield. Further delay in clipping, however, resulted in significant reductions of grain yields. Grain yields for both winter wheat and winter rye were highest for August 28 seeding, although a delay in maturity of about 5 days was noticed as compared with earlier seeding dates. Final height of plants was not affected to any great extent by clipping treatments or by different seeding dates.

4. <u>Response of Winter Rye to 2, 4-D and Picloram Applied at Various Growth Stages of the Crop in Fertile Soil at Ellerslie</u>

The winter rye variety Sangaste was treated at five different growth stages starting from the pre-emergence and continuing until early heading. The rates applied were 0.140, 0.280 and 0.420 kg/ha (2, 4 and 6 oz/A) of picloram as potassium salt and 0.560, 1.120 and 1.680 kg/ha (8, 16 and 24 oz/A) of 2, 4-D as ethyl ester. The lowest dosage of picloram (0.140 kg/ha) and of 2, 4-D (0.560 kg/ha) despite some evidence of crop injury, caused no statistically significant reduction in grain yield. The higher dosages of

both herbicides, however, caused a significant reduction in plant height and grain yield for all stages of treatment. Although measured differences between applications at different stages of growth were not significant, the 4-5 leaf stage (late fall spraying) apparently was most sensitive of all stages included as indicated by various morphological abnormalities and deformed heads.

With the exception of the effect from 0.420 kg/ha (6 oz/A) of picloram, the grain weight per bushel was not decreased to any appreciable extent by the application of different doses of two chemicals. The moisture percentage and percent calcium of grain was, on the whole unaffected by herbicide treatments. The protein percentage and percent phosphorus of grain apparently was inversely associated with yield, and when no yield changes occurred with treatment, neither of the herbicides had any effect on these constituents.

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